Proposals for the implementation of direct seeding mulch-based cropping systems in Khon Kaen and Chiang Maï provinces - Thailand

Florent Tivet
Johnny Boyer
Pascal Lienhard

CIRAD / PERSYST – UR SIA
Mars 2013

Persons met

Mr. Kriangsak Hongto (director of LDD), Mr. Anusorn Chantanaroj (deputy director LDD), Mrs. Kreeyaporn Devahastin (director of international affairs LDD), Mr. Anuwat Pothinam (director of extension department in Konkhaen province), Mrs. Supattra Butolaung (director for LDD of the Land development Royal project operation center), Mrs. Pothinam (director of research section within the extension department of LDD, Konkhaen province), Mrs. Manasanan Chainurat (LDD Konkhaen), Mr. Kran Trisoporn (LDD Chiang Maï), Mr. Autit Tachachaï (LDD Chiang Maï), Mr. Somkid Chumpathong, Mrs. Narisara, and Mr Shafaqat Ali Nadeem from Machine Auto Part (Saraburi).

Schedule

- Arrival in Bangkok on March 5th: travel to Khon kaen,
- March 6th: visit of LDD station and exchanges with farmers
- March 7th: discussion with LDD staff and travel from Khon kaen to Bangkok and from Bangkok to Chiang Maï
- March 8 and 9th: exchanges with LDD team, presentation of DMC systems (principles, methods, experiences in Brazil and in Southeast Asia) and field visits in Chiang Maï. Return to Bangkok on March 9th
- March 11: exchanges with the director, deputy director and international affairs of LDD in Bangkok
- March 12: visit of Machine Auto part

Acknowledgements

We are very grateful to Mr. Anuwat Pothinam and the teams from Khon Kaen and Chiang Maï provinces for the arrangement and the exchanges during the mission.

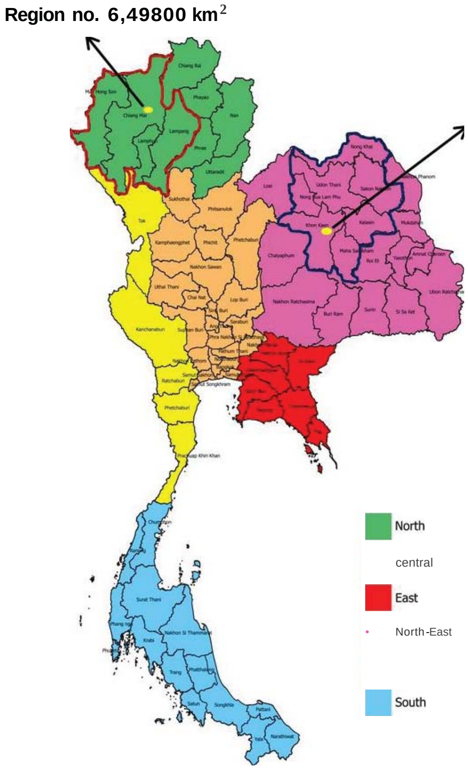
Background

Two previous missions have been conducted by Stéphane Boulakia (2012) and Lucien Séguy et al. (2012) in Thailand. In addition, representatives of LDD visited several farmers in France (Hubert Charpentier, Jean-Claude Quillet, Sarah Singla, Sandrine Gallon & Alain Coudrillier) involved in DMC systems and supported by Lucien Séguy. Additional exchanges were carried-out between LDD and CIRAD teams during the 3rd regional conference on CA in Hanoï. Following these events, representatives of LDD have expressed their wishes to formalize a partnership with CIRAD/URSIA, and to establish first experiments and demonstration fields in Chiang Maï and Khon Kaen provinces.

LDD is organized around several main offices (i.e., research & development, science for land development, surveying and mapping, soil survey and land use planning, engineering) and twelve regional offices. The duties and responsibilities of regional offices include soil survey and analysis, farm planning, and seed production. They also conduct experiments, carry out research on various aspects of land development, produce materials for soil improvement and bio-control, supervise farmers in soil and water conservation, and transfer technology to farmer and others relevant officers. Our partner, Mr. Anuwat Phothinam is in charge of the extension department of the regional office no. 5, including 7 provinces (i.e., Khon kaen, Nong Khai, Udon Thani, Karasin, Sakon Nakhon, Nongbua lampoon, and Maha Sarakham). Thus, this regional office is in charge of one of the main agricultural region of Thailand, comprising by large biophysical, socio-economic and farming systems diversity. The regional office no. 6, located in Chiang Maï, supports the activities in 4 provinces (i.e., Chiang Maï, Mae Hong Son, Lamphun, Lampang) plus the Land development Royal project operation center, which supports 38 royal projects.

The Thai state, under the auspices of its development planning agencies, identified the secondary cities of Chiang Mai and Khon Kaen as growth poles in the 1970s. Both cities were perceived as engines of regional development in their respective regions of North and Northeast Thailand. The area and production of the main crops of rice, cassava, maize, soybean, sugarcane, and rubber are given on the following figure.

Fig. 1: Main regions in Thailand, area and yield of the main crops (data from 2010)



Crops	Area (ha) North	Area (ha) North-East	Total Thailand	Yield (Ton and m^3 for rubber) North	Yield (Ton and m^3 for rubber) North-East
Rice	2293119	6374627	12295698	7873860	13 266330
Maize	735599	316111	1104 870	3059950	1276790
Soybean	68014	23669	114966	81545	22990
Cassava	229003	652587	1326740	5298175	14493229
Sugar cane	374200	455000	1029260	18710 000	22750000
Rubber	97000	450000	2675000	3710	154900

Thailand agricultural total area is ~ 20.9 million hectares. Tapping area of rubber = 1 820 000 ha, mean yield = 1.74 t/ha. The north and northeast regions experienced an increase of rubber plantation since 2006. Sugarcane production has ranged from 47 to 7S million tons between 2000 to 2010, due to wheather pattern and volatile world sugar price. Thailand is a key sugar supplier for international market, and particularly ASEAN countries and Japan.

The aim of the present mission was to provide technical assistance to LDD (1) to identify experimental units, (2) to define a range of cropping systems and technologies (i.e., show room of relay/cover crops and forage species) to implement regarding the specificities of each province and farmers' socio-economic conditions, (3) to propose a detailed protocol for the establishment and the following-up, (4) to identify the purchase of specific technologies (i.e., machinery, species), and (5) to identify the connections to be built-up between Thailand, Cambodia and Lao teams to promote exchange of knowledge and technologies.

Regarding the funds available, the time remaining before the rainy season and the impossibility to have a full involvement of CIRAD staff this year, the following proposal exclusively focused on two demonstration fields (one per province), exchanges (staff and farmers) between Thailand and Laos, and between Thailand and Cambodia, the need to purchase equipments and inputs for the coming and future program, and the need to formalize an institutional partnership between LDD and CIRAD.

Context and prerequisite

As already reported during the previous missions, there is an urgent need to stop the land degradation process, related to the continuous and intensive ploughing and disking operations that favor:

- Soil erosion,
- Continuous depletion of soil fertility under plow-based tillage with less than 1% of OM in the soil surface layer in Khon Kaen. The annual input of biomass-C does not compensate the C outputs (i.e., grains, straws, soil erosion and oxidation of soil organic C stock). We can estimate than ~ 12 Mg DM ha^{-1} yr^{-1} is necessary to maintain a positive balance of soil organic C under DMC management,
- Low porosity and compaction due to successive ploughing and disking operations,
- Low water retention capacity on the sandy soil of Khon Kaen, exacerbated by the depletion of OM and the lack of residues on the soil surface (bare soil),
- Exportation of nutrients is greater than the annual input, generating a continuous depletion of the soil chemical status, and induced plant's physiological disturbance. Thus, greater amounts of mineral fertilizer or manure are needed to compensate the exportations.

The current negative impacts on soil management and decreasing trend of productivity call for pronounced holistic changes of the practices. Efficient management of soil and water must go hand-in-hand with the use of a large biodiversity in production systems, to increase cropping systems productivity, reduce production cost, increase net income while reducing the inter-annual variability, and enhance ecosystem services. Before to start the implementation of DMC systems the main nutrients deficiencies should be corrected, the soil restructured and levelled (when needed), and the perennial grasses controlled.

Methods

The method, described in the previous reports of Boulakia (2012) and Séguy et al. (2012), is driven by the needs to:

- Reply to the urgent need of farmer to stop land degradation, and to advance on farm sustainability,
- Engage the farmers on the process,
- Anticipate the changes,
- Prioritize the constraints (i.e., agronomic, technical, economic),
- Give a technical and economic dimension to the experimental process at each level (i.e., on-station, farm network and pilot extension network).

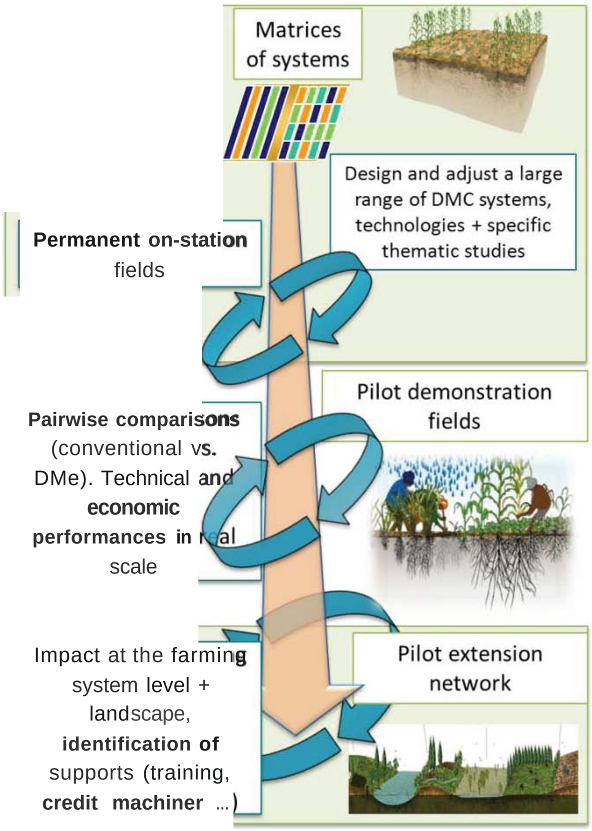
Thus, the approach relies on the design and the evaluation of cropping systems at three different scales:

(1) Experimental units (on-station matrices of systems/thematic trials) with the main objectives:

- To enlarge the range of cropping systems, biodiversity, and technologies to be attractive for farmers,
- To be used as a support to develop know-how, but also for learning and training,
- To produce knowledge and to support specific research studies.

(2) Pilot demonstration fields (on-farm) to assess the most promising systems, and to evaluate the efficiency of innovative cropping systems,

(3) Pilot extension network (evaluation of the conditions for adoption/diffusion).



Under controlled conditions different tools are developed: a range of DMC systems that are reproducible and discriminant for the main agronomic functions (i.e., soil fertility and water management, weeds and pests management…); demonstration fields to compare the conventional systems (reference) to various DMC systems on the basis of a multi-criteria assessment (i.e., agronomic, economic, thematic); a large diversity of species and cultivars; thematic trials for the adjustment of cropping systems (i.e., fertilizer, cultivars, spacing, rules for species association…), and seed production to enlarge the activities.

The continuum of scale is essential, but based on the background from Cambodia and Laos, it could be interested for the next cropping season (2014) to implement the activities through farm networks with pairwise comparisons between the conventional practices and DMC systems. Several pairwise (conventional *vs.* 3-4 DMC systems) can be implemented and replicated on each location/village. This would give us on a short-term basis a deep agronomic and economic assessment. It must be taken into account 3 basic principles: (1) to compare the traditional system with DMC on the same field with the same agricultural story and physical conditions (i.e., soil, topography), (2) to choose the most contrasting soils to assess the performance of the systems, their stability given the biophysical variability of the environment, and (3) to choose farmers highly motivated, to promote an effective dissemination and agree to commit for several years in the implementation and evaluation of such systems. Then, on a second step, large demonstration units on-station could be implemented to fulfill all the functions required (i.e., design of DMC systems, specific thematic/research studies useful for the adjustment and optimization of the systems, learning/training support, seed production…).

Khon Kaen Province

1- Context

Brief presentation of LDD staff and operations

In average, 3 persons are in charge of 4 districts in the province (total of 26 districts), and they are all based in Khon kaen station. No experiments have been seen in the main station of LDD (N 16°28' E102°50', 154m asl). A second station, located 70 km from Khon kaen (Kud Rung, N 16°03' E102°59', 170m asl), has been closed five years ago, and was dedicated to seed production of cover/relay crops.

The LDD gives support to farmers around three main components:

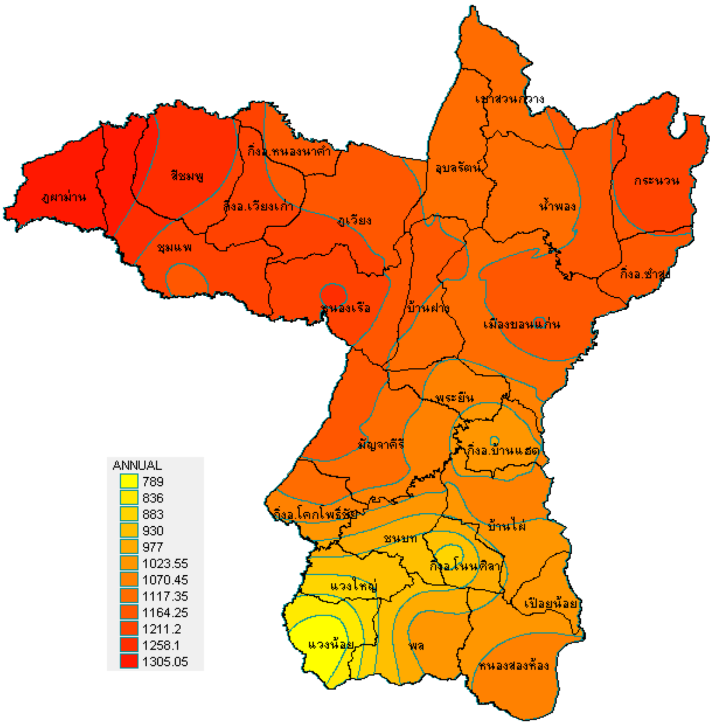
- Provide limestone: 1.5 to 1.8 T/ha for an annual capacity of ~ 1000 ha. The LDD has an overall stock of 2000 tons per year and this activity runs since more than 15 years (high cost of the limestone ~ $65/ha). Gypsum was provided previously but this support has ended several years ago.
- Network of soil doctors, which is the cornerstone of all support given by LDD. On each village one farmer receives training from LDD staff, materials and products (like the 'efficient micro-organisms' products). He is in charge to spread the information amongst the others and his farm is used as a support for training and exchanges.
- Collect and package (jointly with the livestock department?) seed produced by smallholders. LDD is also in charge of producing/packaging the EM products (around 7 different products used for biocontrol (*Trichoderma*, *Bacillus*...), and to enhance soil biological activity...).

Dolomite and EM products to be given to farmer's groups

Biophysical considerations

Rainfall: from May to October (1200 to 1400 mm). Soils are sandy and loamy sandy, with less than 5% of clay in 0-70 cm depth, and OM content less than 1% in 0-20 cm depth (Table 1). In addition, Na accumulation can be a constraint in several locations. The use of gypsum can be useful, facilitating the lixiviation of Na in deeper soil layers. Low CEC (< 5 cmolc/dm^3 in soil surface layer). Additional soil analysis are provided on appendix 3.

Fig. 1: Isohyets map of Khon Kaen Province



Cropping systems

The cropping systems have been described by Boulakia (2012) and Séguy et al. (2012). Sugar cane, upland rice, and cassava are the main rainfed crops of the province, and are of major importance both for the farmers (cash crops) and the agro-industrial sector. On the visited region (southern part of Khon kaen, Ban Wang Va: N16°13' E102°47', 219m asl), the cultivated area per family is 10 to 15 rai of rainfed (1.5 to 2.5 ha) and 4 to 5 rai of lowland (~ 0.8 ha). Following discussions with few farmers the following numbers are reported:

Sugar cane

- Main cropping system: two years of sugar cane followed by one year of rice.
- Yield of sugar cane: from 90 to 60 T/ha.
- Established at the beginning of the dry season and during the dry season mainly to have a good establishment before the rainy season and to reduce the competition by weeds.
- Disk ploughing (1st: 3600 THB/ha; 2nd time: 1800 THB/ha) after rice harvesting.
- Labors for planting 3600 THB/ha + sugar cane stems 7200 THB/ha.
- Fertilizers: 1st one 4800 THB/ha (16-16-8; 300 kg/ha), 2nd from 4800 to 7200 THB/an (15-15-15 or 16-16-8 or 16-8-8, approximately 300 kg/ha). The 2nd application is buried through 'weeding and ridge' operation with buffalo. Total amount of mineral fertilizer of ~ 100 kg/ha of N, 100 kg/ha of P_2O_5 and 50 kg/ha of K_2O.
- Manual weeding: twice during the cycle (30 days after planting and 3 months after planting), 10 men/ha * 220 to 250 THB/day, 4400 to 5000 THB/an.
- Harvest: from 3600 to 6000 THB/ha.
- Truck loading: 3000 THB/ha.
- Selling price: 1000 THB/ton

Productivity of sugar cane decreases drastically after the second year of cultivation, and most farmers shift after that to rice cropping. This limited number of cropping seasons may induce high production costs (i.e., sugar cane planting for a two-year period, increasing use of mineral fertilizer to balance soil fertility depletion) and may explain why cassava is the dominant crop for small – medium farmers while sugar cane is more widespread among larger one. On average, the sugar cane generated from 20,000 ($670) to 30,000 THB/ha ($1000) of net income. Cassava can replace sugar cane in the rotational sequence (after rice) according to market price. Cassava is cultivated on ridges, with important soil erosion on bare and tilled sandy soils. Almost 50% of the cultivated area of cassava is located on the north-eastern region (Figure 1).

Compost is used but large amount is not available, and farmer usually broadcast compost on one part of the rainfed land every year. Compost is usually inoculated with some EM products.

Rainfed rice

- Upland rice can be sowed after two years of sugarcane or after cassava.
- Land preparation in May: burning of sugar cane residues and disk ploughing (1 to 2), followed by 1 off-set harrowing, and mechanical opening of a trench before sowing. However, the sowing seems to be in 'spot' and not in row.
- 20^{th} of June is the deadline for sowing in the vicinity of Khon Kaen.
- Mineral fertilizers: two applications, one at sowing time and 2^{nd} three weeks after sowing
- In average, yield ranges from 2100 to 2800 kg/ha.

A rough estimated of nutrients exportation by sugarcane, rice, cassava, maize, and bean is given in the following table as a tool to evaluate the amount of fertilizer to be added to compensate nutrients exportation, and to assess the efficiency of DMC systems in enhancing the soil fertility.

Table 2: Rough estimation of nutrients exportation

Nutrients	Sugar cane (60 t/ha)	Rice (2,5 t/ha)	Cassava (20 t/ha)	Maize (6,0 t/ha)	Bean (1,5 t/ha)
	kg ha^{-1}				
N	75	38	90	78	57
P	10	9	17	24	7
K	69	7	132	29	32
Ca	24	2	22	2	5
Mg	21	3	12	9	5
S	15	2	10	7	15

Table 1: Soil analysis from Khon Kaen province

Depth	Horizon	Particle size (g/kg)			pH		P, mg/kg	C	Ca	Mg	K	Na	Acidity	Sum Cations
		sand	silt	clay	1:1 water	1:1 KCl	Bray II	%	cmol/kg					
						Maha Sarakham								
0-23	Ap	85,5	12,0	2,5	5,5	5,0	8,8	0,54	1,8	0,3	0,1	0,2	2,1	4,5
23-38	AE	83,8	14,2	2,0	5,6	5,1	3,8	0,16	0,9	0,1	0,04	0,2	0,7	1,94
38-70	E	86,4	11,6	2,0	6,6	5,9	4,0	-	0,6	0,1	0,04	0,2	0,5	1,44
70-95	Bt1	72,2	12,5	15,3	6,0	4,8	6,8	0,08	2,2	0,7	0,1	0,2	1,7	4,9
95-130	Bt2	67,7	15,5	16,8	5,4	4,0	7,9	0,05	1,8	1	0,1	0,3	1,8	5
130-180	Bt3	71,6	12,1	16,3	5,1	3,6	4,4	0,07	1,2	0,8	0,2	0,3	2,2	4,7
180-210	Bt4	64,8	13,2	22,0	4,6	3,6	8,5	0,09	1	1,1	0,3	0,3	3,7	6,4
						BanPhai series								
0-15	Ap	89,5	8,5	2,0	5,5	4,7	7,0	0,21	0,74	0,13	0,05	0,05	1,98	2,95
15-30	E1	87,8	8,7	3,5	5,2	4,1	10,0	0,13	0,52	0,07	0,05	0,15	2,44	3,23
30-60	E2	84,9	9,6	5,5	5,6	4,2	4,0	0,05	0,53	0,17	0,05	0,88	2,25	3,88
60-80	Bt1	63,4	8,5	28,1	4,5	3,5	3,0	0,14	0,62	0,52	0,13	0,23	2,13	3,63
80-110	Bt2	60,9	10,0	29,1	4,7	3,6	3,0	0,11	0,28	1,92	0,09	0,13	5,5	7,92
110-160	Bt3	64,8	10,1	25,1	4,7	3,7	3,0	0,09	0,55	1,6	0,07	0,1	3,83	6,15
160-200	Bt4	66,6	10,5	23,0	4,7	3,7	3,0	0,2	1,32	1,45	0,08	0,22	3,28	6,35

2- Demonstration field (first as a learning support)

One unit will be established in the main station but should be seen only as a support to exhibit few DMC systems and as a learning support for LDD team. The demonstration field will comprise the three main crops of the region: sugarcane, cassava, and upland rice.

It is emphasized that no experimental design (no replicates per cropping system) is followed due to the size of the field (Fig. 2). Thus, this site can't be in the future a support to design cropping systems, to aggregate a large diversity of species, to train people, to produce technical and scientific knowledge, and to produce seeds for future extension activities. It has to be emphasized that LDD has to provide consistent areas and means (human and funding) to this program. A second option could be to implement most of the activities with farmer groups through the soil's doctor network, and pairwise comparisons between farmer's practices and DMC systems. However, designing innovative system and conducting specific research topics should be done in station. In addition, LDD staff needs diversified training support, and long-term experiments should be built in the future in the own LDD's stations.

Land preparation

In April, the field should be levelled and chemically corrected before the implementation of any trials. Soil surface will be levelled with the use of disk harrow or covercrop, followed by two passes of cultivator or chisel plow with a roller in a next in line, which slightly press the soil, so that it will stay in place. Dolomite, gypsum, and micronutrients should be broadcasted before land preparation or at least before the passes of the cultivator or chisel plow. In case of strong occurrence of perennial grasses (and broad leaves), glyphosate (3l/ha) + 2.4-D (1.5 l/ha) will be used in late April or beginning of May.

Soil correction

Regarding soil analysis, dolomite and gypsum should be applied plus S, and micronutrients (i.e., Mn, Zn, Bo, Cu…) at the following rate:

- Dolomite 2.0 t/ha, or [dolomite 1.5 t/ha + 0.5 t/ha gypsum];
- $MnSO_4$ (20 kg/ha), $ZnSO_4$ (20 kg/ha), Bo (10 kg borax/ha), $CuSO_4$ (10 kg/ha), and Sulfur (30 kg/ha). In addition, foliar application of 2kg/ha of $MnSO_4$ and $ZnSO_4$, 1kg/ha of B, and 0.5 kg/ha of $CuSO_4$ could be necessary at the early stage of growth (first tillering stage of rice, sorghum and others cover/relay crops).

Use of gypsum:

- to replace Na,
- Ca from surface applied gypsum leaches to subsoil and is absorbed by roots,
- Gypsum as a Ca source in plant nutrition (sugar cane) is as effective as limestone on Ca-deficient soils,
- Increasing importance as a source of S, essential in C-depleted soils (1 kg S per 60 kg of C in organic matter; ~2% of organic S mineralized per year = ~ 9 kg S/ha/yr are mineralized for each 1% of SOM in the top 20 cm),
- In subsoil Ca^{2+} exchange with Al^{3+}, complex ion $AlSO_4$+ not toxic to plant roots.

Another option will be the use of thermophosphate (1.5 to 2.0 t/ha) instead of dolomite, as a source of P (16%), CaO (28%), MgO (21%), SiO_2 (28%), and some micronutrients. Due to the high deficiency in sulphur it would be more efficient to use, when possible, the sulphate of ammonium, and the single superphosphate that contains ~ 18% of Ca and 11% of S, respectively.

Micronutrients and gypsum can be purchased through the following providers. A first quotation of micronutrients has been received from Tim-Bor (see appendix 1).

Products	Provider
Micronutrients (Bo, Mn, Zn, Cu)	Tim-bor distributor in Thailand 22/2 Moo2, Soi Jadsarntaharnrua Chalermprakiet Rama 9 Rd Dokmai, Praves, Bangkok 10250, Thailand 66 2-726-7300 / 7350, contact: numchai@boracarethai.com
Gypsum	Vanich Gypsum Co., info@thailandgypsum.com; http://www.thailandgypsum.com/ Southern Group: http://www.gypsum-thailand.com/

DMC systems

Small-scale demonstration fields for upland rice, sugar cane and cassava will be implemented. Three blocks will be established per crop: (1) conventional plow-based tillage (reference), (2) bio-pump or stylo (*S. hamata* or *guianensis*) sowed before sugar cane, and (3) stylo (*S. hamata* or *guianensis*) or *C. rotundifolia* associated to rice and cassava (Fig. 2).

The three main blocks (i.e., rice, cassava and sugar cane) can rotated as follow, but we should keep in mind that the cropping systems are not fixed and can be modified any time depending of the evolution of the cropping systems, and for learning and training purpose.

Table 4: DMC systems in Khon Kaen Station

DMC	*2013*	*2014*	*2015*	*2016*
DMC 1	Cassava + stylo or wynn cassia	Rice + stylo or wynn cassia	Sugar cane + stylo after harvest Or Sugarcane on living cover of wynn cassia	Sugar cane + stylo or wynn cassia
DMC 2	Bio-pump + sugar cane Or *S. hamata* + sugar cane	Sugar cane + stylo or wynn cassia after harvest	Sugar cane + stylo or wynn cassia	Rice + stylo or wynn cassia Or Cassava + stylo or wyn cassia
DMC 3	Rice + stylo or wynn cassia	Cassava + stylo or wynn cassia	Rice + stylo or wynn cassia Or Cassava + stylo or wyn cassia	Sugar cane + stylo or wynn cassia after harvest

Sugar cane

Block bio-pump

- Establishing a bio-pump (mix of species – enhancing the synergies amongst species) of sorghum (10 kg/ha) + finger millet (6 kg/ha) + *C. cajan* (15 kg/ha) + *C. juncea* (10 kg/ha) at the end of May
- Rolling and controlling (glyphosate + 2.4-D) the bio-pump end of September

- Opening a furrow with a chisel plow at the end of October beginning of November
- Planting cassava

Block Stylo

- Sowing of the stylo at the end of May
- Rolling (and controlling (glyphosate + 2.4-D) if necessary) the stylo end of September
- Opening a furrow with a chisel plow at the end of October beginning of November
- Planting of sugarcane in November

Block reference

- Plowing and harrowing end October – beginning November
- Opening a furrow with a chisel plow
- Planting of sugarcane in November

Cassava

Block Stylo and C. rotundifolia (wynn cassia)

- Cassava planting + sowing of stylo (6 kg/ha) and *C. rotundifolia* (4 kg/ha) 25 days after planting

Block reference

- Plowing and harrowing in May
- Cassava planting and conventional crop management (weeding)

If it's too late to plant the cassava the same pattern than for the sugar cane can be followed, with the sowing of a bio-pump in May, rolling/spraying at the end of September to beginning October, opening furrows with a chisel plow, and planting of cassava.

Rice

Block Stylo and C. rotundifolia

- Rice sowing + pre-emergent (pendimethaline, 3l/ha) in May + sowing of stylo (6 kg/ha) and *C. rotundifolia* (4 kg/ha) 25 days after rice sowing

Block reference

- Plowing and harrowing in May
- Rice sowing and conventional crop management (weeding)

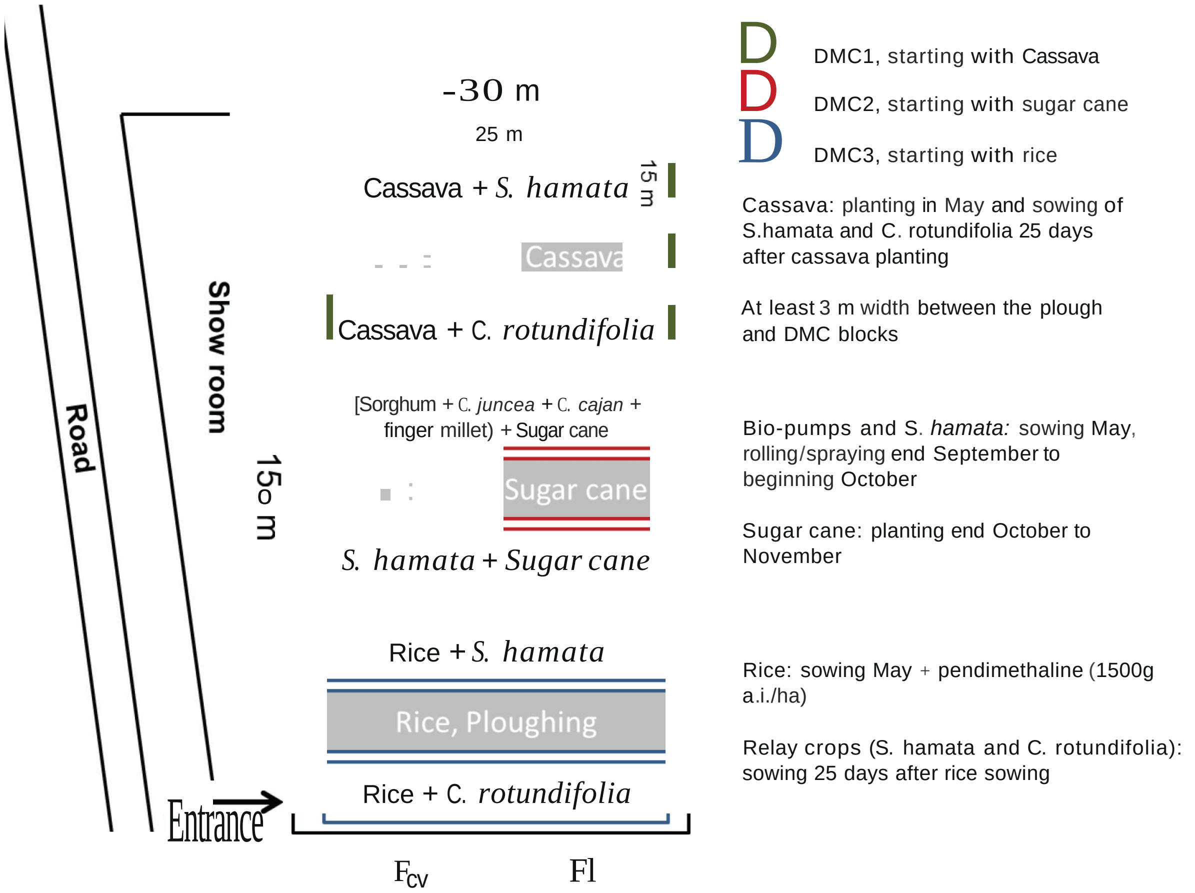
Due to limited area only two levels (i.e., F_{CV} = conventional use of mineral fertilizer, and F1 to compensate the exportation by the stems, grain and roots) of mineral fertilizer will be applied.

Table 5: Mineral fertilization for cassava, rice and sugarcane

Crop	Conventional	F1	F2
Basal fertilization	farmer's practice	2 Mg/ha of limestone or [1,5 Mg/ha of limestone + 0,5 Mg/ha of gypsum] 30 kg/ha sulfur, 20 kg/ha $MnSO_4$, 20 kg/ha $ZnSO_4$, 10 kg/ha B, 10 kg/ha $CuSO_4$	
Cassava	farmer's practice	**$62N$-$54P_2O_5$-$90K_2O$** *20 DAP* 100 kg/ha 16-20-0 + S 75 kg/ha 0-46-0 75 kg/ha KCl (0-0-60) *30 days later* 100 kg/ha urea 75 kg/ha KCl	**$101N$-$86P_2O_5$-$120K_2O$** *20 DAP* 200 kg/ha 16-20-0 + S 100 kg/ha 0-46-0 100 kg/ha KCl *30 days later* 100 kg/ha urea 100 kg/ha KCl *70 DAP* 50 kg/ha urea
Bio-pump + Sugar cane	farmer's practice	**$91N$-$95P_2O_5$-$105K_2O$** *Sowing of bio-pump* 100 kg/ha 16-20-0 + S 50 kg/ha KCl *Planting sugar cane* 200 kg/ha 15-15-15 *End April, beginning May* 300 kg/ha 15-15-15	**$106N$-$156P_2O_5$-$180K_2O$** *Sowing of bio-pump* 100 kg/ha 16-20-0 + S 50 kg/ha KCl *Planting sugar cane* 300 kg/ha 15-15-15 *End April, beginning May* 100 kg/ha KCl 100 kg/ha 0-46-0 300 kg/ha 15-15-15
Rice	farmer's practice	**$50N$-$43P_2O_5$-$30K_2O$** *Sowing* 100 kg/ha 16-20-0 + S 50 kg/ha 0-46-0 50 kg/ha KCl *25 DAS* 75 kg/ha urea	**$100N$-$86P_2O_5$-$60K_2O$** *Sowing* 200 kg/ha 16-20-0 + S 100 kg/ha 0-46-0 50 kg/ha KCl *25 DAS* 100 kg/ha urea *40 DAS* 50 kg/ha KCl 50 kg/ha urea

For the coming cropping season, specific experiments should be carried-out to integrate the compost (inoculated with EM products) used by farmers.

Fig. 2: Demonstration field in LDD's station in Khon Kaen (flat land). The distance between the plough and the DMC blocks should be at least of 3m to avoid a progressive degradation of the DMC blocks.



3- On-farm demonstrations: pairwise comparisons

For the coming cropping seasons (2014), several pairwise comparisons can be established based on the main rotational sequence of farmers (i.e., two years of sugarcane followed by cassava or upland rice). Several species of cover/relay crops can be used and established on each crop and compared with the conventional farmer's practices. Some examples of DMC systems are given in Table 6.

As reported by Séguy et al. (2012), two options are available for the direct sowing of sugar cane under DMC management:

- Mechanized sowing using sugar cane no-till planter produced in Brazil
- Manual sowing after the opening of a furrow into the mulch using a modified cultivator with cutting disc in front of the shanks. Another possibility would be to contact Machine Auto Part Co., Ltd to develop a prototype with cutting disc and coulter for no-till sugarcane and cassava.

Table 6: Potential DMC systems to be tested on-farm through pairwise comparisons

Pairwise comparisons CV vs. DMC	*2014*	*2015*	*2016*
DMC1	After sugarcane direct sowing of rice on sugarcane residues	Sugarcane on residues of rice + sowing of stylo after 1st harvest	Sugarcane + stylo or sugarcane on living cover
DMC2	After sugarcane direct sowing of rice on sugar cane residues + *S. hamata* or *C. pascuorum*, *Alysicarpus*	Sugarcane on: • residues of rice + *S. hamata* Or • Living cover of *C. pascuorum*, *Alysicarpus*	Sugarcane + stylo after 1st harvest Or Sugarcane on living cover
DMC3	Cassava + *S. hamata* or *S. guianensis*	Rice + stylo (25 DAS)	Sucarcane + stylo after 1st harvest
DMC4	1st cycle of sugarcane + sowing of *S. hamata*, *S. guianensis* … after 1st harvest	2nd cycle of sugarcane + stylo	Cassava + stylo (30 DAP) Or Rice + stylo (25 DAS)

Sugar cane – Planting in November

Sugar cane – Planting in February

Cassava on ridge – Planting in February

Sugar cane – Planting in February

Sugar cane – October

Rainfed rice - October

Chiang Maï Province

1- Context

Brief presentation of LDD staff and operations

The visit was organized by Mr. Anuwat Pothinam (LDD Khon kaen), and with the staff of LDD of Chiang Maï (Mrs. Supattra Butolaung, Mr. Kran Trisoporn, and Mr. Autit Tachachaï). Mrs. Supattra is in charge of the support and following of 38 royal projects in 4 provinces (Land development Royal project operation center). As in every province, an intensive work of soil classification has been done. This work is mainly conducted by the LDD team of Konkhaen.

Four main locations have been visited: (1) LDD station in Chiang Maï and Maetang vetiver propagation station, (2) Nonghoï Royal Project (70 km from Chiang Maï), (3) Kea Noï Royal Project close to the border with Myanmar (< 10 km), and (4) Nhong Keaw Royal Project.

Biophysical considerations and cropping systems

Maetang station (N 19°07' E98°56'): focused on vetiver production for soil erosion control (hedgerow). A fallow (5 years) of almost 1.8 ha has been selected to implement a demonstration field mainly focused on maize, upland rice, and legumes.

Nonghoï (1200 m asl): focused on vegetable production through the support of a royal project. Dynamic that started almost 20 years ago. Three cycles per year with irrigation in the dry season, and heavy use of organic manure, mineral fertilizer and pesticides. High level of diversification (Chinese cabbage, basilica …).

Kea Noï (Royal Agricultural Station, Fang District, Chiang Mai Province, Ang Khang): royal project that has been implemented 25 years ago, close to the border with Myanmar (910 asl, 1650 mm, minimum temperature of 5°C, Tmean of 20°C).

Parent materials: shale and limestone. Good soil fertility with ~ 6.4% of OM in the top soil layer under native vegetation, and an effective CEC of 15 cmol/kg (appendix 4).

Social context: Three main ethnic groups (i.e., Thai Yai, Chinese Yunnan, Muser), 4200 people in two villages and 12 sub-groups. Few families have access to the lowland, mostly 5 rai of upland per family up to 15 rai. Thai Yai and the Chinese groups have enough rice, it's not the case for the Muser. These communities still live in strong interactions with the surrounding natural resources and a clear figure should be drawn, before any actions to be implemented, to identify the interactions between farming systems (annual and perennial crops, livestock) and forest resources (i.e., NTFP …).

Farming systems:

- Vegetables production
- Legumes in rotation with upland rice: one year of legume (two crops/year) followed by one year of rice. Land preparation is based on disk ploughing ($90/ha). Two legumes are mainly used: *Phaseolus vulgaris* and *Vigna angularis* (cv. Azuki). The latter is sold in Taiwan, Pakistan, and Japan. Estimated yield of 1.2 to 1.5 t/ha for *P. vulgaris* and Azuki. Selling price ranging from $500 to $800/ton for the phaseolus, and from $560 to $630/ton for Azuki. Use of gramoxone after sowing and before the second legume crop managed under NT.
- Upland rice after legumes. Yield of ~ 3 t/ha with the use of 50 N, 25 P_2O_5 and 25 kg/ha K_2O.

- Maize is mainly produced for local consumption and livestock.
- Fruits: high diversity of species with passion fruit, plum, mango, cape grossberry (*Physialis peruviana*, \$2.5/kg), and Japanese apricot. Small quantities are produced locally, only 6 t/year of the cape grossberry, and 10 t/year for the Japanese apricot.
- Buckwheat (1.2 t/ha) is commonly produced by the Chinese group. Recently, the royal project has introduced 3 cultivars from Japan and market chain will be evaluated in the coming years.

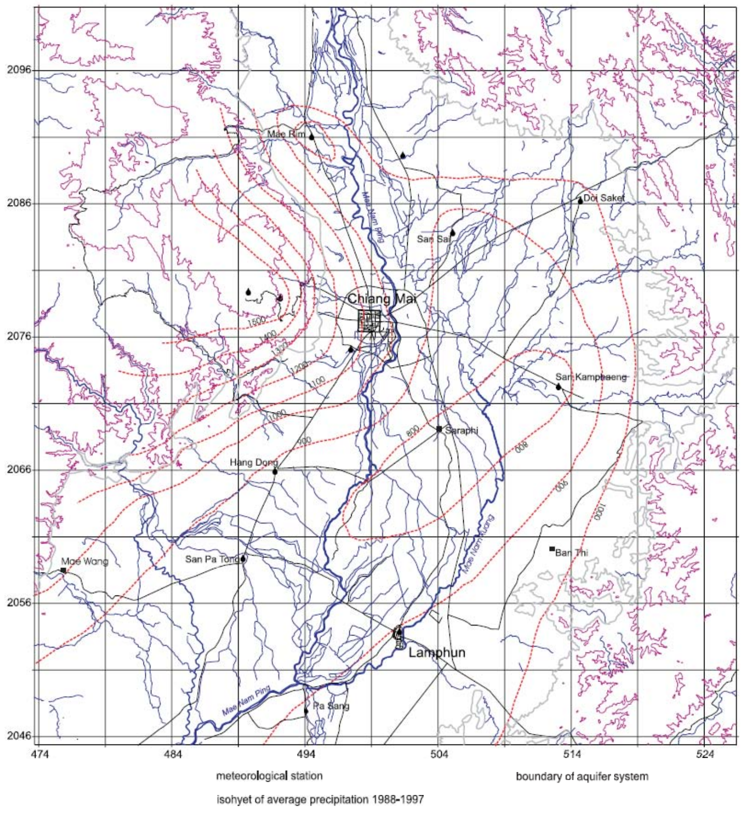
Nhong Keaw region (680 to 780 m asl)

Parent materials: limestone and/or shale. Good soil fertility under native vegetation (Nhong Keaw 1 and 2, appendix 4) with ~ 7.0% of OM in the top soil layer, and an effective CEC that ranged from 17 to 28 cmol/kg. By contrast, SOM content decreased to 3.4% under arable lands in the top soil layer, representing a depletion of SOM when compared with the native vegetation. However, these comparisons are not easy due to differences of topography, position on the landscape, and eventually nature of the parent materials.

Cropping systems are mainly focused on maize, black bean, peanut, and upland rice production. No lowland paddy fields, and most of the families buy rice for self-consumption. Maize: land preparation is based on disk ploughing (\$50/ha), yield ranges from 7 to 9 t/ha with the following amount of fertilizer 90 N-90P_2O_5-90K_2O, hybrids from CP and others companies are used (50 to 60\$/15 kg). Use of gramoxone after sowing and atrazine in post-emergence. Sowing of black bean 30 days before maize harvesting. Following discussions with staff of the royal project the production cost of maize was (over)estimated to > \$1000/ha, with an over-estimation of the cost of harvest (\$600/ha):

- Hybrid seed \$60/ha
- Fertilizer \$360/ha
- Ploughing \$50/ha
- Herbicide and labor \$50/ha
- Harvest \$600/ha

Rainfall distribution in the vicinity of Chiang Maï (from Margane and Taton, 1999) with a large gradient from 800 to 1500 mm/year



Nong Hoï – Horticulture production

Maetang Station

Nhong Keaw (terracing performed by LDD). Main rainfed crops: maize, rice and black bean (cowpea). Parent materials: limestone and shale

2- Demonstration field

For the same reason than KonKhaen (limited funding and time remaining before the rainy season), only one demonstration field plus a show room of species will be implemented in Maetang station. In the future, on-farm demonstrations (pairwise comparison between conventional practices and innovative cropping systems) can be rapidly implemented in Nonghoï and in Nhong Keaw region. The dynamics of the farming systems are close to the dynamics observed in Cambodia and in Laos.

One unit will be established in Maetang station and the objective is similar to that of Khon kaen station, i.e. as a support to show/exhibit few DMC systems and not as an experimental field for specific research studies. Demonstration field (on flat land) of maize, upland rice, and legumes (*Vigna umbellata*, *Vigna unguiculata*, *V. angularis*, and *P. vulgaris*) will be implemented.

First, the land should be levelled and chemically corrected if needed (no soil analysis has been provided to evaluate the chemical fertility of the site). As presented for Khon kaen, the land can be prepared by the use of disk harrow/covercrop followed by a chisel plow or cultivator + roller to create soil porosity and to level the soil surface. Micronutrients (20kg/ha $MnSO_4$, 20kg/ha $ZnSO_4$, 10kg/ha $CuSO_4$, 10 kg/ha B) and sulphur (30 kg/ha) should be broadcasted before land preparation or at least before the use of the cultivator or chisel plow. Before the establishment of the demonstration plots, weeds will be control with the use of glyphosate (3l/ha) + 2.4-D (1.5l/ha) at the end of April to early May.

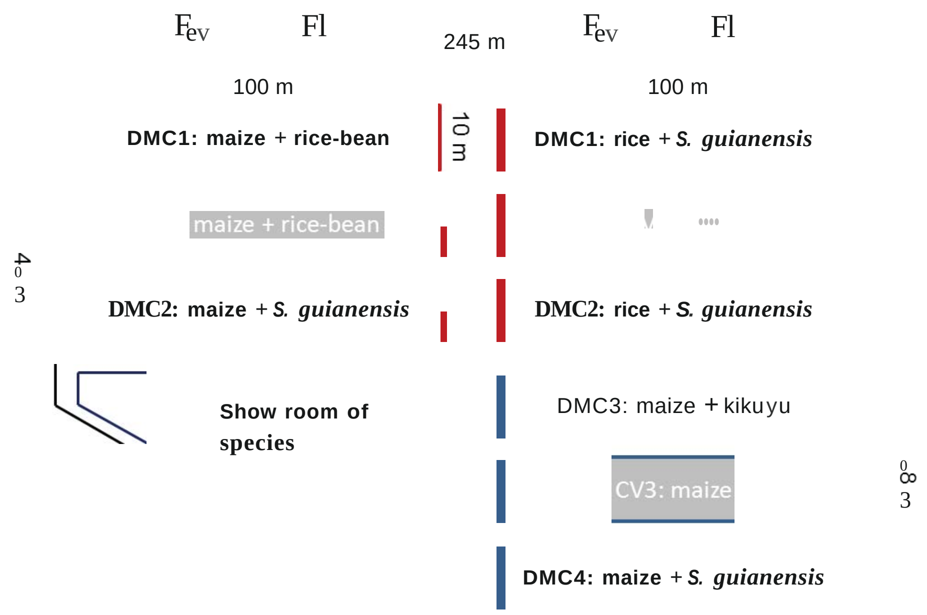
The experiment can de designed as a simple matrix (large plot per treatment with no real replicate) for this first year. The following DMC systems could be implemented.

Table 7: DMC systems in Chiang Maï

DMC	*Year 1*	*Year 2*	*Year 3*
DMC 1	Maize + legumes (cowpea or rice-bean)	Rice + *S. guianensis*	Maize + legumes (cowpea or rice-bean)
DMC 2	Maize + *S. guianensis* (6 kg/ha)	Rice + *S. guianensis*	Maize + *S. guianensis*
DMC 3	Maize + kikuyu grass (5 kg/ha)	*P. vulgaris*, *V. angularis*, cowpea, or soybean on living mulch of kikuyu	Legumes on living mulch of kikuyu
DMC 4	Maize + *S. guianensis*	*P. vulgaris* or *V. angularis* or cowpea on *S. guianensis*	Maize + *S. guianensis* Or Rice + *S. guianensis*

DMC systems can be adjusted and extended the following years in function of the dynamics of that region, the technical background of LDD team, and to anticipate the changes.

Two levels of fertilizers are given: the conventional practices (F_{CV}), and a second level to compensate the exportation of nutrients by the grains (F1). One of the main constraints with the legumes (i.e., rice-bean, black bean and *P. vulgaris*) is that most of the stubble is exported from the field to thresh the grain. It is estimated that bean as *P. vulgaris* exports ~ 10 kg S/t of grain. Three levels of fertilizers are given on the following table but only F_{CV} and F1 can be applied regarding the size of the field.



CV: conventional plow-based tillage
DMC: direct seeding mulch-based cropping system

Show room of species

Maize & Rice: sowing in May + pendimethaline (1500g a.i.lha)

S. *guianensis:* sowing 25 days after rice and maize sowing

Rice-bean (V. *umbellata)* or black bean (*V. unguiculata):* sowing **30 days before maize harvest**

Kikuyu *(P. clandeslinumj:* sowing 25 days after maize sowing

At least 3m width between the CV and the DMC blocks

Table 8: Mineral fertilization for maize and rice

Crop	Conventional	F1	F2
Basal fertilization	farmer's practice	2 Mg/ha of limestone or [1,5 Mg/ha of limestone + 0,5 Mg/ha of gypsum] 30 kg/ha sulfur, 20 kg/ha $MnSO_4$, 20 kg/ha $ZnSO_4$, 10 kg/ha B, 10 kg/ha $CuSO_4$	
Maize	farmer's practice	**78N-63P_2O_5-60K_2O** *Sowing* 200 kg/ha 16-20-0 + S 50 kg/ha 0-46-0 100 kg/ha KCl (0-0-60) *25 days later* 100 kg/ha urea	**101N-86P_2O_5-90K_2O** *Sowing* 200 kg/ha 16-20-0 + S 100 kg/ha 0-46-0 100 kg/ha KCl *25 days later* 150 kg/ha urea 50 kg/ha KCl
Rice	farmer's practice	**50N-43P_2O_5-30K_2O** *Sowing* 100 kg/ha 16-20-0 + S 50 kg/ha 0-46-0 50 kg/ha KCl *25 DAS* 75 kg/ha urea	**100N-86P_2O_5-60K_2O** *Sowing* 200 kg/ha 16-20-0 + S 100 kg/ha 0-46-0 50 kg/ha KCl *25 DAS* 100 kg/ha urea *40 DAS* 50 kg/ha KCl 50 kg/ha urea

3- On-farm demonstrations: pairwise comparisons

Based on the background from Laos and Cambodia pairwise comparisons can be established in 2014. Some examples of DMC systems are given in Table 9.

Table 6: Potential DMC systems to be tested on-farm through pairwise comparisons

Pairwise comparisons CV vs. DMC	*2014*	*2015*	*2016*
DMC1	Maize + *C. cajan* or *C. juncea* or *Desmanthus virgatus*	Rice + *S. guianensis*	Maize + *C. cajan* or *C. juncea* or *Desmanthus virgatus*
DMC2	Maize + rice-bean or black bean intercropped 30 days before maize harvest	Maize + rice-bean or black bean intercropped 30 days before maize harvest	Rice + *S. guianensis*
DMC3	Maize + *S. guianensis*	Rice + *S. guianensis*	Maize + *S. guianensis*
DMC4	Maize + kikuyu	*P. angularis*, *black bean* or soybean + kikuyu	*P. angularis*, *black bean* or soybean + kikuyu

Common activities in Khon kaen and Chiang Maï Provinces

1- Show room of species

Show room will be established on each province with however some specificities for the sandy soils of Khon Kaen province. As recommended during the last mission (Séguy et al., 2012), native species of *Alysicarpus*, *M. atropurpureum* and *Indigofera hirsuta* have been collected by farmers in Khon kaen province. The **collection and multiplication of native legumes** has to be extended during the coming cropping season. It is of major importance since they are well adapted to this agroecology and could be used in future cropping systems design:

• *Alysicarpus p*. whose development is better than *Arachis pintoï* in sandy soils and that could be used as permanent living cover in cassava, rice, and/or sugar cane cropping systems.

• *Macroptilium atropurpureum* (*Siratro*), well adapted to sandy soils, to be used in association with *Brachiaria ruziziensis*, *Chloris gayana*, *Cenchrus ciliaris* … and with maize + *Centrosema pascuorum* (cv. Cavalcade).

• *Indigofera hirsuta*, that can be used in association with sorghum, millet, finger millet + legumes such as *Crotalaria juncea, Centrosema pascuorum, Sesbania sp.*

• *Sesbania* sp.

Additional species, well adapted to the sandy soils of Khon Kaen Province has to be introduced:

• *Cenchrus ciliaris* (Buffel – cultivars biloela, Gayndah, USA) well adapted to sandy soil and drought conditions.

• *Chloris gayana* (Rhodes – cultivars Callide, Katambora) … as improved pasture and/or suitable living cover for the cultivation of edible beans (e.g., soybean, mung bean, rice bean, common bean).

• *Cassia rotundifolia* (Wynn cassia), also well adapted to sandy soils, to be used in association with forage grasses (*Brachiaria ruziziensis*, *Chloris gayana*, *Cenchrus ciliaris*) … and with maize, sorghum, rice.

• *Stylosanthes hamata* (cv. Verano), also well adapted to sandy soils and that could be used similarly to *Stylosanthes guianensis* CIAT 184 … good association with chloris, cenchrus, panicum…

In addition, others species useful for the design of DMC systems and/or for the integration with livestock activities should be purchased.

• *Macrotyloma axillare* (Java) (from Matsuda, Brazil, www.matsuda.com.br, e.matsuda@uol.com.br).

• *Desmanthus virgatus* (hedge Lucerne), a leguminous shrub evaluated in the livestock stations several years ago as an alternative plant protein feed ingredient to the expensive soybean meal commonly used in fattening activities (i.e., poultries, pig). Well adapted to basic acid and could be used in association with sorghum, finger millet. This specie could be evaluated in both provinces but Chiang Maï will be more suitable.

• *Mimosa invisa* spineless that has been evaluated by the team of LDD from Chiang Maï (Mr. Autit) in the past.

• *Brachiaria marandu* (MG4, MG5…) from Matsuda Brazil;

• Kikuyu (*Pennisetum clandestinum*) cv. Whittet and Noonan. This perennial grass can be an excellent living cover crop for the legumes (i.e., soybean, cowpea, rice-bean), and can also be used as a fodder resource.

• Bahia grass (*Pennisetum notatum*) well adapted to acid soil, persisting under high rainfall conditions but also under dry conditions, and can be used to develop DMC systems for legumes on living cover.

A first quotation from Wrighton Seeds in Australia, and from Matsuda (Brazil) are given in appendix 2 for Rhodes, Buffel and Wynn cassia.

Option 1: Regarding the available area, small plot (50-100 m^2) of each species plus the 'common' species of *Brachiaria* (i.e., ruzi, decumbens, marandu, humidicola, mullato), *Panicum maximum*, *S. guianensis* will be established. Based on exchanges with the livestock department, LDD has to provide a clear figure of the available species.

Option 2: if larger plots can be identified, these species could be established on at least 1000 m^2 plot to produce seed for the coming season. Even if the means are limited for 2013, LDD staff and CIRAD have to anticipate on the future activities that could be implemented. In addition, plots of **association between several species** ($100m^2$) can be established as a tool for LDD staff to assess the technical requirement, the potential of these species to improve on a short-term period the soil fertility. All species can be sown as a mix or in row. Large combinations can be tested and the following associations can be extended by the persons in charge of these activities.

Example for Khonkaen:

- *C. cajan* (15 kg/ha) + *C. pascuorum* (6 kg/ha) + *D. virgatus* (4 kg/ha)
- *E. coracana* (6 kg/ha) + *C. cajan* (15 kg/ha) + *C. rotundifolia* (4 kg/ha)
- *E. coracana* (6 kg/ha) + *C. juncea* (15 kg/ha) + *S. guianensis* (6 kg/ha)
- Sorghum (10 kg/ha) + *C. juncea* (15 kg/ha) + *C. rotundifolia* (4 kg/ha)
- Sorghum (10 kg/ha) + *C. juncea* (12 kg/ha) + *Alysicarpus*
- Sorghum (10 kg/ha) + *B. ruziziensis* (10 kg/ha) + *C. rotundifolia* (4 kg/ha)
- *B. ruziziensis* (10 kg/ha) + *S. hamata* (6 kg/ha) or *S. guianensis* (6 kg/ha)
- *….*

Example for Chiang Maï:

- *E. coracana* (6) + *C. cajan (15)* + *D. virgatus* (4)
- *E. coracana* (6) + *C. juncea* (15) + *S. guianensis* (6)
- Sorghum (10) + *S. guianensis* (6) + *C. pascuorum* (6)
- Sorghum (10) + *C. cajan* (15)
- *C. pascuorum* + kikuyu
- *…*

Table 7: Quantity required per specie for 2013 cropping season

Specie	**Quantity (kg)**	**Providers**
B. ruziziensis, *B. decumbens*, *B. mullato*, *B. humidicola*, *B. brizantha* (marandu, MG4, MG5)	5	Thailand and Matsuda for *B. brizantha* cv. Marandu, MG-4 and MG-5
P. maximum	5	Thailand
Pennisetum notatum (Bahia grass) and *P. clandestinum* (kikuyu)	5	Southedge, Heritage seeds or Matsuda
S. guianensis (CIAT 184)	5	Thailand
S. hamata (Verano)	5	Thailand, Southedge or Heritage Seeds
C. pascuorum	10	Thailand
C. rotundifolia (Wynn cassia)	5	Southedge or Heritage Seeds
Cenchrus ciliaris (Buffel)	5	Southedge or Heritage Seeds
Chloris gayana (Rhodes)	5	Southedge or Heritage Seeds
Java (*Macrotyloma axillare*)	5	Matsuda
C. juncea, *C. spectabilis*, *C. retusa*, *C. ochroleuca*	10, 5, 5, 5	Thailand and from Cambodia and/or Laos
Sesbania	5	Thailand
Desmanthus virgatus	5	Thailand
Mimosa invisa spineless	1	Thailand
Sorghum, millet, finger millet	15, 5, 10	See Cambodian team of PADAC
Rice-bean (*Vigna umbellata*)	25	See Lao team

2- Machinery

Following a previous survey of Pascal Lienhard, there are great opportunities to adapt seeders (maize, rice, legumes) and planting machines for cassava and sugar cane under NT management with Machine Auto Part Co. located in Saraburi province (150 km from Bangkok). A visit has been organized on 12th of March with Stéphane Boulakia. Machine Auto Part has already brought from PADAC team (Cambodia) one sowing row of the VenceTudo. They will develop a first prototype (based on the cutting and sowing disks of VenceTudo) that would be tested for the coming cropping season in Cambodia. Unfortunately, it will be too late to evaluate this prototype in Xayabury province (Laos) during the sowing period of maize (mainly end of April to beginning of May).

It is interesting to observe that equipment for medium-size tractors (18 to 30 hp) are widely used in Thailand. This dynamic contrast with the former one mainly based on 'large' tractors (70 to 90 hp), and emphasized the wish of smallholders to have their own equipment and to be independent of the service provider. By contrast, the current dynamics in Laos (Sayaboury, Xieng Khouang, Oudomxay) and Cambodia (Battambang province for example) focused mainly on the use of heavy mechanization (large number of second hand tractors and seeders in Battambang coming from Thailand, similar to the dynamic observed in Sayaboury/Laos in the late 90's). Several equipments have to be purchased by LDD in 2013:

- Two manual fertilizer broadcaster (Solo, http://www.solo-germany.com/)
- Planters (maize, soybean, rice, one per province):
    - Two seeders for power tiller (hand tractor) or small-size tractor (two rows),
    - Two seeders for larger tractor (three to four rows for maize).
- Cultivator or chisel plow for land preparation, but also sugar cane and cassava establishment under NT systems.

- Two rolling knife for power tiller and two rolling knife for medium-size tractor.
- Sprayers (2 units) for small tractor or power tiller.
- Hand jab seeders (Fitarelli or Krupps from Brazil).

The planters (after the improvement of their current seeders), sprayers, chisel plow or cultivator can be purchased in Machine Auto Part (Somkid Chumpathong and Shafaqat Ali Nadeem, Machine Auto Part Co., Ltd, Thailand (Tel: +66 36-266725, Fax: +66 36-266478, somkid_chumpathong@hotmail.com).


Four row seeders from Machine Auto Part

Fertilizer broadcaster from Solo + sprayer

Knife roller (picture from Cambodia, PADAC)

Chisel and roller. Use a roll cage rather than others

3- Weeds control

The availability of the following herbicide has to be checked.

Active ingredient	Herbicide	Dose (g ha^{-1}, l/ha)	Use
Pendimethaline	Herbadox	600 – 1200 g ha^{-1}	Pre-emergence: rice, corn, cotton, soybean
Oxadiazon	Ronstar	500 g ha^{-1}	Pre-emergence: rice, soybean …
Acétolachlore		5 l ha^{-1}	Pre-emergence: can be used on corn/sorgho and cover/relay crops (crotalaria, stylo, sesbania, centrosema)
Flumioxazine	Flumyzin	20 – 25 g ha^{-1}	Can be used to control mix of cover/relay crops: ruzi + crotalaria, sorghum…
Bentazone	Basagran	600 – 720 g ha^{-1}	Can be used in post on corn + cover/relay crops (ruzi, crotalaria, stylo, finger millet, centrosema) Product that can be used on a large range of crops: rice, soybean, bean … and efficient to control the genus *Cyperus* (early stage)
Metsulfuron or carfentrazone	Allié, Aurora	Metsulfuron (5g ha^{-1}) or carfentrazone (5 g ha^{-1})	Efficient to control broad leaves on rice
Cyhalofop	Clincher	0.8 - 1l ha^{-1}	Specific for rice (post-precoce, control annual grass)
Mesotrione	Callisto	1-1.5 l ha^{-1}	Post for corn, sugar cane
Clethodim	Centurion, Ogive	120 – 180 g ha^{-1}	Post and very efficient on annual and perennial grass. Specific on several broad leaves species

Priorities

A list of the main activities to be conducted urgently on the coming weeks is given herein.

To be purchased:

- micronutrients (appendix 1), limestone and gypsum, and looking for thermophosphate availability in Thailand,
- Limestone (1 ton for Khon Kaen, 4 tons for Chiang Maï), gypsum (0.25 ton for Khon Kaen, 1 ton for Chiang Maï), thermophosphate (6 tons),
- mineral fertilizers (Khon Kaen: 200 kg of 16-20-0, 100 kg of 0-46-0, 200 kg of 0-0-60, 150 kg/ha of 46-0-0, 300 kg/ha of 15-15-15; Chiang Maï: 600 kg of 16-20-0, 200 kg of 0-46-0, 300 kg of 0-0-60, 350 kg/ha of 46-0-0),
- see the availability of machinery: covercrop, cultivator or chisel plow + roller cage,
- contact with Machine Auto Part to purchase: 4 rolling knife (2 for hand-tractor and 2 for medium-size tractor), two 200L sprayers, 4 backpack sprayers (2 per province), see in late May/June the prototype of planter that will be develop for Cambodia. If the prototype is successful, 2 planters for hand-tractor and 2 planters for medium-size tractor could be purchased,
- two manual fertilizer broadcaster SOLO,
- herbicide to be used after land preparation,
- seeds with Wrighton in Australia and Matsuda in Brazil (see quotation in appendix 2),
- Contact the livestock department, universities, and others LDD departments to purchase the following species: *S. guianensis*, *S. hamata*, *C. pascuorum*, *Desmanthus virgatus*, *Crotalaria* sp., *Sesbania*, *Cajanus cajan*, *Mimosa invisa* spineless (see Mr. Autit, Chiang Maï), *Brachiaria* sp., *Panicum maximum*,
- all species/seeds/stems for the species to be used: maize, rice, cassava, sugarcane, black bean, *Phaseolus vulgaris*,
- contact the teams from Cambodia and Laos to receive the following species and cultivars: sorghum, pearl millet, finger millet, *Crotalaria* sp., *C. cajan*,

To be done:

- Prepare the land on the stations in Khon Kaen and in Chiang Maï (Maetang):
  - Use of covercrop, cultivator or chisel plow with a roller cage,
  - Broadcast limestone + gypsum + micronutrients before the land preparation,
  - Control end of April, beginning of May the weeds with the use of glyphosate + 2.4-D
- Prepare all tools needed to establish the experiments, and to mark all plots.

Exchanges with LDD in Bangkok

Two exchanges have been organized with the direction of LDD in Bangkok: the first one with Mr. Kriangsak Hongto (director of LDD) to present the first activities that could be implemented in both provinces and the need to formalize a partnership between LDD and CIRAD/URSIA. The second exchange, with Mr. Anusorn Chantanaroj (deputy director LDD), Mrs. Kreeyaporn Devahastin (director of international affairs), and Mr. Anuwat Pothinam, was specifically focused on the steps to follow within LDD to formalize the partnership. A first version of a MOU, developed by Jean-Claude Legoupil, was discussed. Mrs. Kreeyaporn Devahastin suggested going through the redaction of a general MOU between LDD and CIRAD, followed by specific agreements on key research and development issues that LDD and CIRAD will be interested to develop jointly. It was decided that Johnny Boyer will send to Mrs. Kreeyaporn Devahastin, a first version of a general MOU.

Final comments

The number of demonstration/experimental units was defined with LDD according to the available resources (financial, human) for the coming cropping season. Two units on LDD stations have been selected: one in Khon kaen and the second in Chiang Maï (Maetang station) provinces. For the coming season, LDD has to purchase agricultural equipments (i.e., planting machine, sprayers, rolling knife…) to be use on-station and within the future on-farm demonstrations network. We proposed, that one CIRAD staff located in the region give technical and scientific support to LDD staff to start these first demonstrations, show room, and to give some support to purchase the equipments. Due to the lack of time to carry-out a full survey few information were collected regarding the structure and the diversity of farming systems in both provinces. Such information is essential and can be collected in 2013.

Based on the experiences from Cambodian and Lao teams it could be easy to adapt DMC systems to the biophysical and socio-economics conditions observed in Khon kaen and Chiang Maï provinces. Regarding the issues on each province, on-farm demonstrations network (pairwise fields: conventional *vs.* DMC system) should be implemented rapidly in order to demonstrate on a short-term basis the efficiency of DMC systems to sustain crop productivity, to improve soil fertility, and to advance in farm sustainability. Such a network is essential to adapt the systems and technologies to the specific conditions of each region and farms, and to be used for learning and exchanges between farmers and extension staff.

In both provinces, activities have to be based for the next cropping season (2014) on the 'soil's doctors network', using the structure and the background of the royal projects. These latter have introduced a large diversity of annual and perennial species, and have a deep understanding of the dynamics (i.e., agricultural systems, market access, credit, ethnics groups).

In addition, the continuum between Laos, Thailand and Cambodia is essential. Exchanges between countries have to be planned to take advantages of the backgrounds from Laos and Cambodia. A first visit of LDD team and Thai farmers could be planned in Cambodia before July 5th, visiting the dynamics in Battambang province, as well as the demonstration and research fields in Kampong Chan province (Bos Khnor). LDD staff has to visualize, and understand, the role of such demonstration and research fields supporting the design of cropping systems, learning support, training & communication, seed production, biometric evaluation of the systems (producing knowledge and strong scientific foundations), and to anticipate the changes of the farming systems. Visit in Laos could be planned at the end of the rainy season or earlier depending of the activities implemented in Laos and the team availability. In addition, exchanges between Laos and Cambodia have to be scheduled to enhance farmer to farmer exchanges (farmers speaking to farmers) and to boost the adoption of DMC systems.

Regarding the infrastructures of research, higher education, extension, and private sector, Thailand could be in the future the main focal point in the region to consolidate education and training on conservation agriculture and DMC systems.

Based on the expected MOU that would be established between LDD and CIRAD, LDD has to clarify its intentions, as well as its human and financial supports to these activities. Regarding the large biophysical and socio-economic diversity of the north and northeastern region (11 provinces), a master plan should be developed for the next 5 years, describing the geographical interventions, the projected DMC systems, the support to produce knowledge and to anticipate the changes, the network of on-farm demonstrations, the connections to build between LDD staff, royal projects and extension staff based on each district, the keys research topics (i.e., biophysical: water balance, SOC sequestration, physical properties, biological activity; and socio-economics: organizing farmer groups, specific incentives, agricultural policies…), the human resources from LDD and CIRAD, and the funding. The priority will be given to upland agriculture that is of major importance to sustain farmers' livelihood and the local agroindustry-based economy. However, regarding the large area of lowland rice in the northeastern provinces of Thailand, the intensification of lowland rice production should be a second priority.

Appendix 1 – Quotation of micronutrients from Chieng Thai Trading, Thailand

CHIENG THAI TRADING CO., LTD.
บริษัท เชียงไทยเทรดดิ้ง จำกัด

เลขที่ *QU56/03055*

วันที่ 27 มีนาคม 2556

เรื่อง เสนอราคา

เรียน Khun Anuwat Pothinam

LOO Khon Kaen, Thailand.

Email: anuwat07@hotmail.com.florent.tivet@cirad.fr

บริษัทฯ มีความยินดีขอเสนอราคาผลิตภัณฑ์ ดังรายการต่อไปนี้ .-

ลำดับที่	ชื่อการค้า	ขนาดบรรจุ	จำนวน	ราคา/หน่วย	จำนวนเงิน
			kgs	บาท	บาท
	Neobor	25kgs/Bag	50.00	42.00	2,100.00
2	Manganese Sulfate (MnSo4)	25 kgs/Bag	50.00	48.00	2,400.00
3	Zine SUlfate (ZnSo4)	25 kgs/Bag	50.00	50.00	2,500.00
4	Sulfer Powder (S)	25 kgs/Bag	50.00	48.00	2,400.00
5	Copper Sulfate (CuSo4)	25 kgs/Bag	50.00	95.00	4,750.00
			รวมเงินสุทธิ		14,150.00

หมายเหตุ

1.ราคาสินค้าไม่รวมภาษีมูลค่าเพิ่ม และค่าขนส่ง

2.เงื่อนไขการชำระเงินสด โอนเข้าบัญชี

ห้างหุ้นส่วนจำกัด เชียงไทยเทรดดิ้ง

ธนาคารกสิกรไทย สาขาเอกมัย บัญชี ออมทรัพย์

เลขที่บัญชี 059-2-34474-2

3.โอนเงินเข้าบัญชีเรียบร้อยแล้วกรุณาแฟกซ์ใบโอนเงินมาที่ โทร.02-726-2433

ขอแสดงความนับถือ

นายนำชัย ลอยฤทธิวุฒิไกร

081-8412443

7 Chalermprakiet Rama 9 Soi 48 Yak 4, Dokmai, Praves, Bangkok 10250, Thailand
7 ซอยเฉลิมพระเกียรติ ร. 9 ซอย 48 แยก 4 แขวงดอกไม้ เขตประเวศ กรุงเทพฯ 10250
Tel. +66 2 726 7300 Fax : +66 2 726 7350
E-mail : **info@chiengthai.com** **www.chiengthai.com**

Appendix 2 – Quotation from Wrighton – Australia and Matsuda - Brazil

PGG Wrightson Seeds
Australia

24 Tinaroo Creek Rd (P.O. Box 1502)
Mareeba, Queensland, 4880
Ph: 07 4086 2400 Fx: 07 4092 2345
Email: cbertoldo@pggwsa.com.au
ABN: 83 004 227 927

Quotation

ACCOUNT:

Mr Anuwat Pothinam
LDD Khon Kaen
Thailand

Invoice Number: EQ25032013

Date: 25/03/2013

Exporter's Ref: CIRAD, LOAS

Payment Terms: Prepaid

Due Date:

Goods Description	Qty	Price	Amount IAUD)
ENVIROGRO® Katambora Rhodes (Chloris gayana)	5	$ 10.00	$ 50.00
ENVIROGRO® Wynn Cassia (Chamerchrista rotundifolia)	5	$ 16.00	$ 80.00
ENVIROGRO® Callide Rhodes (Chloris gayana)	5	$ 13.00	$ 65.00
ENVIROGRO® Biloela Buffel (Cenchrus ciliaris)	5	$ 13.00	$ 65.00
ENVIROGRO®Gayndah Buffel (Cenchrus ciliaris)	5	10	$ 50.00
Dpcumentation, Fumigation, Phytosanitary Certificate	1	$ 375.00	$ 375.00
Door To Door Courier Service 25kg Of Seed	1	$ 345.00	$ 345.00

EFT - Direct Deposit
Account Name: PGG Wrightson Seeds Ltd
Bank - Westpac Bank - Seven Hills, Sydney
BSB Number: 032-179
Account Number:000S08

Subtotal	$	1,030.00
Tax		
TOTAL		$1,030.00

Consignment consists of 1 x 25kg package containing 5x 5kg white poly bags

MATSUDA

COM. INO. MATSUOA IMP. E EXP. LTOA

RODOVIA RAPOSO TAVARES, KM 575 - ALVARES MACHADO - SP, BRASIL
CEP 19160-000 - TEL.(18)3226-2000 FAX (18) 3273-1622
E-MAIL: mtsd.sp@uol.com.br

COMMERCIAL
INVOICE *022/2013*

A MACHADO , 03 APRIL 02 , 2013

MR. ANUWAT POTHINAM
LDD KHON KAEN
THAILAND
PHONE: 006689861 7531
E-MAIL : anuwat07@hotmail.com

QUANTITY	UNIT.	PRODUCT	PRICE US$ PIKG	TOTAL US$
		PASTURE SEED		
05	KG	(MG-4) BRACHIARIA BRIZANTHA CV MG-4	10,80	54,00
05	KG	(MG-5) BRACHIARIA BRIZANTHA CV MG-5 VITORIA	10,80	54,00
05	KG	(B.BRIZANTHA) BRACHIARIA BRIZANTAHA CV MARANDU	8,70	43,50
05	KG	(MACROTILOMA,DOLICOS) MACROTYLOMA AXILLARE CV JAVA	10,90	54,50
		TOTAL F.O.B. - GUARULHOS - SP		206,00
		INSURANCE		200,00
		FREIGHT		216,50
		TOTAL C.I.F. BANGKOK - THAILAND		622,50

NET WEIGHT : 20 KG
GROSS WEIGHT 22 KG
TIPE OF PAKING: MULTIPAPER AND NYLON BAG
PAYMENT FORM : BANK TELETRANSMITION
POINT SHIPMENT : GUARULHOS - SP - BRAZIL
POINT LANDING : BANGKOK - THAILAND

Appendix 3 - Soil analysis in Ban Wang Wa, Ban Had District Khonkaen province

Soil sampling from 12 farmers growing rice, 10 farmers growing sugarcane, and 11 growing cassava (depth/horizon 0-15 cm)

Table 1: upland rice

Soil analysis / No.farmer	pH (1:1)H_2O	EC(1:10) (ms/cm)	Lime requirement (Kg/rai)50%	%OM	%N	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
1.Mr.Boonkarn	5.09	0.03	156	0.17	0.01	7	118.2	113.5
2.Mr.Chamnan	5.6	0.03	-	0.25	0.01	8	115.9	112.1
3.Mr.Kampai	5.67	0.03	-	0.28	0.01	5	191.5	138.1
4.Mr.Vichai 1	5.77	0.04	-	0.21	0.01	7	158.9	113.9
5.Mr.Vichai 2	5.15	0.03	156	0.29	0,02	15	115.5	115.2
6.Mr. Tavin	5.67	0.05	-	0.36	0.02	6	147.4	138.6
7.Mr.Sommai	5.4	0.03	156	0.19	0.01	9	132.1	112
8.Mr.Kumpong1	5.86	0.04	-	0.24	0.01	7	137.6	121.5
9.Mr.Kumpong2	5.88	0.04	-	0.25	0.01	7	140.8	103.3
10.Mr.Surin	5.78	0.03	-	0.23	0.01	10	215.6	146.7
11.Mr.Yongyai	7.62	0.02	-	1.07	0.05	139	5,097	206.7
12.Mr"Tongda	5.10	0.07	156	0.27	0.01	94	501.1	173.4

Table 2: Cassava

Soil analysis / No.farmer	pH (1:1)H_2O	EC(1:10) (ms/cm)	Lime requirement (Kg/rai)50%	%OM	%N	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
1.Mrs.Dang	4.95	0.03	156	0.12	0.01	7	118.2	128.2
2.Mrs.Tongdee	5.68	0.03	-	0.19	0.01	4	128.5	113.9
3.Mrs.Kaesorn	6.51	0.05	-	0.24	0.01	22	229.4	156.1
4.Mrs.Priwan	5.79	0.04	-	0.28	0.01	25	303.6	160.6
5.Mrs.Lumpri	5.29	0.04	156	0.07	0,00	5	111.7	125.0
6.Mrs.Wongdeun	5.47	0.04	156	0.18	0.01	10	177.8	144.1
7.Mrs.Pranee	5.38	0.03	156	0.25	0.01	4	129.9	118.5
8.Mrs.Ratchanee	6.05	0.03	-	0.28	0.01	14	134.4	137.6
9.Mr.Boonchan	6.00	0.03	-	0.14	0.01	11	136.1	139.2
10.Mrs.Nooban	5.66	0.04	-	0.35	0.02	7	103.8	127.0

Table 3: Sugarcane

Soil analysis / No.farmer	pH (1:1)H_2O	EC(1:10) (ms/cm)	Lime requirement (Kg/rai)50%	%OM	%N	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
1.Mr.Gunha	5.11	0.04	156	0.04	0.00	15	168.3	134.1
2.Mrs.Sakol	5.68	0.04	-	0.31	0.02	11	141.4	123.2
3.Mr.Suttira	6.12	0.04	-	0.21	0.01	18	145.7	167.4
4.Mr.Thanakorn	5.35	0.03	312	0.09	0.01	5	112.0	135.2
5.Mr.Sungwarn	6.26	0.04	-	0.21	0,01	3	111.9	131.5
6.Mr. Kal	5.31	0.03	156	0.13	0.01	10	142.7	123.6
7.Mr.Sarit	6.37	0.04	-	0.23	0.01	11	182.3	127.4
8.Mr.Prasit	6.18	0.04	-	0.18	0.01	5	210.0	121.1
9.Mr.Noi	5.38	0.04	156	0.19	0.01	25	237.9	135.5
10.Mr.Kumpong1	5.36	0.04	156	0.34	0.02	9	164.1	120.0
11.Mr.Kumpong2	6.07	0.06	-	0.26	0.01	45	192.2	143.4

Appendix 4 – Soils profile in Chiang Maï provinces, Nong Keaw and Nong Hoï locations

<table>
<tr><td colspan="3">Soil profile Description</td></tr>
<tr><td colspan="2">Soil series: ud,iso,f,sh,lb,wd,D,d5</td><td>Profile code No.: Nong keaw-1</td></tr>
<tr><td colspan="3">Soil Classification (1998): fine, kaolinitic, isohyperthermic Typic Kandiudults.</td></tr>
<tr><td colspan="3">Location: Nong keaw Royal Project Ban Nong keaw, Muang Na Sub-District, Chaing Down District Chiang Mai Province.</td></tr>
<tr><td colspan="2">Sheet Name: Ban Na Wai</td><td>Sheet No.: 4748 II</td></tr>
<tr><td colspan="2">Coordinate: 494993E, 2180237N</td><td>Elevation: 756 m. (MSL)</td></tr>
<tr><td colspan="2">Relief: rolling</td><td>Slope: 12-20 %</td></tr>
<tr><td colspan="3">Physiography: erosion surface</td></tr>
<tr><td colspan="3">Parent material: residuum from shale and limestone</td></tr>
<tr><td colspan="2">Drainage: well drained</td><td>Permeability: moderate</td></tr>
<tr><td colspan="2">Runoff: medium</td><td>Ground water depth: -</td></tr>
<tr><td colspan="3">Vegetation and Land use: Wild</td></tr>
<tr><td colspan="2">Described by: Mr. Wutthichart Sirichuaychoo LDD</td><td>Date: 25 August 2009</td></tr>
<tr><td>Horizon</td><td>Depth (cm.)</td><td>Description</td></tr>
<tr><td>A</td><td>0-10/20</td><td>Dark reddish gray (10R3/1) and dusky red (10R3/2) clay loam; weak medium and coarse breaking to fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many medium, coarse and fine roots; neutral (field pH 7.0); clear, slightly wavy boundary.</td></tr>
<tr><td>BA</td><td>10/20-40</td><td>Dusky red (10R3/2) dark red (10R3/6) and red (10R4/6) clay loam; weak fine and medium breaking to fine subangular blocky structure; friable, slightly sticky, slightly plastic; many medium, coarse and fine roots; neutral (field pH 7.0); clear, smooth boundary.</td></tr>
<tr><td>Bt1</td><td>40-70</td><td>Dark red (10R3/6) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; common fine and medium roots; neutral (field pH 7.0); gradual, smooth boundary.</td></tr>
<tr><td>Bt2</td><td>70-110</td><td>Dark red (10R3/6) and red (10R4/6) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine and medium roots; neutral (field pH 7.0); gradual, smooth boundary.</td></tr>
<tr><td>Bt3</td><td>110-150</td><td>Red (10R4/6 and 10R4/8) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine and medium roots; neutral (field pH 7.0); gradual, smooth boundary.</td></tr>
</table>

Bt4	150-200	Red (10R4/6 and 10R4/8) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; neutral (field pH 7.0).

Soil Profile Description		
Soil series: ud,iso,f,sh,hb,wd,E,d5	**Profile code No:** Nong keaw-2	
Soil Classification (1998): fine, kaolinitic, isohyperthermic Ultic Hapludalfs.		
Location: Nong keaw Royal Project Ban Mai Samakee , Muang Na Sub-District, Chaing Down District, Chiang Mai Province.		
Sheet Name : Mae Taeng District	**Sheet No.:** 4747 II	
Coordinate : 495060E, 2101296N	**Elevation :** 772 m. (MSL)	
Relief: hilly	**Slope:** 20-35 %	
Physiography: erosion surfaces		
Parent material: residuum from shale and limestone		
Drainage: well drained	**Permeability:** moderate	
Runoff: medium	**Ground water depth: -**	
Vegetation and Land use: Wild		
Described by: Mr. Wutthichart Sirichuaychoo LDD	**Date:** 25 August 2009	
Horizon	**Depth**	**Discription**
A	0-10	Very dark gray (10YR3/1) and very dark grayish brown (10YR3/2) clay loam; weak fine and medium subangular blocky structure; friable, slight sticky, slightly plastic; many fine and medium, few coarse roots; neutral (field pH 7.0); clear, smooth boundary.
BA	10-20/30	Dark brown (7.5YR3/2) strong brown (7.5YR4/6) and reddish brown (5YR4/3) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; slightly acid (field pH 6.5); clear, wavy boundary.
Bt1	20/30-55	Yellowish red (5YR4/6) and reddish brown (5YR4/4) clay; moderate medium and coarse breaking to fine and medium subangular blocking structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt2	55-90	Yellowish red (5YR4/6) and reddish brown (5YR4/4) clay; moderate medium and coarse breaking to fine and medium subangular blocking structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; moderately acid (field pH 6.0); gradual, smooth boundary.

Bt3	90-130	Yellowish red (5YR4/6) and reddish brown (5YR4/4) clay; moderate medium and coarse breaking to fine and medium subangular blocking structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine roots; moderately acid (field pH 6.0); clear, smooth boundary.
BC	130-160	Dark reddish brown (5YR3/4) reddish brown (5YR4/4) and reddish gray (5YR5/2) clay; moderate medium and coarse subangular blocky structure; ffirm, sticky, plastic; no roots; neutral (field pH 7.0); clear, wavy boundary.
Cr	160-200	Mixed color of weathered shale very dark gray (2.5YN3/) dark yellowish brown (10YR4/4) dark brown to brown (10YR4/3) and brown (7.5YR5/4) clay; no roots; neutral (field pH 7.0).

<table>
<tr><th colspan="3">Soil profile Description</th></tr>
<tr><td colspan="2">Soil series: ud,iso,f,sh,lb,hc,wd,C,d5</td><td>Profile code No.: Nong keaw-3</td></tr>
<tr><td colspan="3">Soil Classification (1998): fine, kaolinitic, isohyperthermic Typic Kandihumults.</td></tr>
<tr><td colspan="3">Location: Nong keaw Royal Project Ban Nong keaw, Muang Na Sub-District, Chaing Down District, Chiang Mai Province.</td></tr>
<tr><td colspan="2">Sheet Name : Ban Na Wai</td><td>Sheet No.: 4748 II</td></tr>
<tr><td colspan="2">Coordinate: 495634E, 2180000N</td><td>Elevation: 782 m. (MSL)</td></tr>
<tr><td colspan="2">Relief: ondulating</td><td>Slope: 5-12 %</td></tr>
<tr><td colspan="3">Physiography: erosion surface</td></tr>
<tr><td colspan="3">Parent material: residuum from shale</td></tr>
<tr><td colspan="2">Drainage: well drained</td><td>Permeability: moderate</td></tr>
<tr><td colspan="2">Runoff: medium</td><td>Ground water depth: -</td></tr>
<tr><td colspan="3">Vegetation and Land use: corn</td></tr>
<tr><td colspan="2">Described by: Mr. Wutthichart Sirichuaychoo LDD</td><td>Date: 25 August 2009</td></tr>
<tr><th>Horizon</th><th>Depth</th><th>Discription</th></tr>
<tr><td>A</td><td>0-10/15</td><td>Dusky red (2.5YR3/2) and dark reddish brown (2.5YR3/4) clay loam; weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; slightly acid (field pH 6.5); clear, smooth boundary.</td></tr>
<tr><td>BA</td><td>10/15-30/35</td><td>Dark reddish brown (2.5YR3/4) and dark red (2.5YR3/6) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; moderately acid (field pH 6.0); clear, smooth boundary.</td></tr>
<tr><td>Bt1</td><td>30/35-75</td><td>Dark red (2.5YR3/6) and red (2.5YR4/6) clay; weak fine and medium subangular blocky structure; friable, sticky, plastic; patchy thin clay coating on ped faces; many fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.</td></tr>
</table>

Bt2	75-115	Red (10R4/8 and 10R4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; common fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt3	115-160	Red (10R4/8 and 10R4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt4	160-200	Red (10R4/8 and 10R4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; moderately acid (field pH 6.0).

Soil profile Description		
Soil series: ud,iso,f,sh,lb,wd,D,d5	**Profile code No.:** Nong keaw-4	
Soil Classification (1998): fine, kaolinitic, isohyperthermic Typic Kandiudults.		
Location: Nong keaw Royal Project Ban Nong keaw, Muang Na Sub-District, Chaing Down District, Chiang Mai Province.		
Sheet Name : Ban Na Wai	**Sheet No.:** 4748 II	
Coordinate: 492612E, 2180709N	**Elevation:** 754 m. (MSL)	
Relief: rolling	**Slope**: 12-20 **%**	
Physiography: erosion surface		
Parent material: residuum from shale		
Drainage: well drained	**Permeability:** moderate	
Runoff: medium	**Ground water depth: -**	
Vegetation and Land use: Wild, corn		
Described by: Mr. Wutthichart Sirichuaychoo, LDD	**Date:** 26 August 2009	
Horizon	**Depth**	**Discription**
A	0-10/15	Dark reddish brown (5YR3/2 and 5YR3 /3) loam; weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; many fine, medium and coarse roots; neutral (field pH 7.0); clear, slightly wavy boundary.
BA	10/15-30/40	Reddish brown (2.5YR4/4) dark red (2.5YR3/6) and dark reddish brown (5YR3/3) clay loam; weak medium and coarse breaking to fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium, common coarse roots; slightly acid (field pH 6.5); clear, wavy boundary.
Bt1	30/40-60/70	Dark red (2.5YR3/6) and red (2.5YR4/6) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on

		ped faces; many fine and medium, few coarse roots; moderately acid (field pH 6.0); gradual, wavy boundary.
Bt2	60/70-100	Dark red (2.5YR3/6) and red (2.5YR4/8) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; many fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt3	100-130	Dark red (2.5YR3/6) and red (2.5YR4/8) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt4	130-160	Dark red (10YR3/6) and red (2.5YR4/8) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt5	160-200	Dark red (10RYR4/6) clay; moderate coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; moderately acid (field pH 6.0).

Soil profile Description	
Soil series: ud,iso,f,sh,lb,hc,wd,C,d5	**Profile code No.:** Nong keaw-5
Soil Classification (1998): fine, kaolinitic, isohyperthermic Typic Kandihumults.	
Location: Nong keaw Royal Project Ban Nong keaw, Muang Na Sub-District, Chaing Down District, Chiang Mai Province.	
Sheet Name: Ban Na Wai	**Sheet No.:** 4748 II
Coordinate: 492837E, 2179500N	**Elevation:** 688 m. (MSL)
Relife: ondulating	**Slope:** 5-12%
Physiography: erosion surfaces	
Parent material: residuum from shale	
Drainage: well drained	**Permeability:** moderate
Runoff: medium	**Ground water depth: -**
Vegetation and Land use: corn, red bean	
Described by: Mr. Wutthichart Sirichuaychoo LDD	**Date:** 26 August 2009

Horizon	**Depth**	**Discription**
Ap	0-15	Dark reddish brown (5YR3/2) and dark reddish gray (5YR4/2) clay loam; weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; few fine and

		medium roots; slightly acid (field pH 6.5); abrupt, smooth boundary.
Bt1	15-35	Yellowish red (5YR5/6) and strong brown (7.5YR5/6) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; patchy thin clay coating on ped faces; few fine and medium roots; moderately acid (field pH 6.0); clear, smooth boundary.
Bt2	35-70	Strong brown (7.5YR5/6) and yellowish red (5YR4/6) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine and medium roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt3	70-100	Strong brown (7.5YR5/6) and yellowish red (5YR5/6) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt4	100-130	Strong brown (7.5YR5/6 and 7.5YR4/6) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; few iron and manganese nodules; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt5	130-170	Strong brown (7.5YR5/6 and 7.5YR5/8) and yellowish brown (10YR5/6) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; few iron and manganese nodules; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt6	170-200	Strong brown (7.5YR5/6 and 7.5YR5/8) yellowish brown (10YR5/6) and light yellowish brown (10YR6/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; moderately acid (field pH 6.0).

Soil Profile Description	
Soil series: ud,hy,f,sh,lb,hc,wd,F,d5	**Profile code No.:** Kea Noi-1
Soil Classification (1998): very-fine, kaolinitic, hyperthermic Typic Palehumults.	
Location: Kea Noi Royal Project Ban chai ya , Muang Na Sub-District, Chaing Down District, Chiang Mai Province.	
Sheet Name: Ban Na Wai	**Sheet No.:** 4748 II
Coordinate: 475128E, 2175505N	**Elevation:** 1,013 m. (MSL)
Relief: steep slope	**Slope:** 35-50 %
Physiography: erosion surfaces	
Parent material: residuum from shale and limestone	

Drainage: well drained	**Permeability:** slow
Runoff: rapid	**Ground water depth: -**
Vegetation and Land use: corn, red bean	
Described by: Mr. Wutthichart Sirichuaychoo LDD	**Date:** 27 August 2009

Horizon	Depth	Discription
Aow1	0-20	Dark reddish brown (5YR3/4) and reddish brown (2.5YR4/4) clay; moderate fine and medium subangular blocky structure; friable, sticky, plastic; many fine and medium roots; slightly acid (field pH 6.5); clear, smooth boundary.
Aow2	20-45	Reddish brown (2.5YR4/4) and red (2.5YR4/8) clay; weak fine subangular blocky structure; friable, sticky, plastic; many fine and medium roots; neutral (field pH 7.0); abrupt, smooth boundary.
Ab	45-55	Dark reddish brown (5YR3/4) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; slightly acid (field pH 6.5); clear, smooth boundary.
Bt1	55-80	Dark red (2.5YR3/6) and red (2.5YR4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine roots; slightly acid (field pH 6.5); gradual, smooth boundary.
Bt2	80-105	Dark red (2.5YR3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; slightly acid (field pH 6.5); gradual, smooth boundary.
Bt3	105-130	Dark red (2.5YR3/6) and red (2.5YR4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; slightly acid (field pH 6.5); gradual, smooth boundary.
Bt4	130-160	Red (2.5YR4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; slightly acid (field pH 6.5); gradual, smooth boundary.
Bt5	160-200	Red (2.5YR4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; slightly acid (field pH 6.5).

Soil Profile Description	
Soil series: ud,hy,f,sh,lb,hc,wd,D,d5	**Profile code No.** Kea Noi- 2
Soil Classification (1998): fine, kaolinitic, hyperthermic Typic Kandihumults.	
Location: Kea Noi Royal Project Ban: Kea Noi , Muang Na Sub-District, Chaing Down District, Chiang Mai Province.	
Sheet Name: Ban Na Wai	**Sheet No.:** 4748 II

Coordinate: 477773E, 2175823N	**Elevation:** 994 m. (MSL)
Relief: rolling	**Slope:** 12-20 %
Physiography: erosion surface	
Parent material: residuum from shale and limestone	
Drainage: well drained	**Permeability:** moderate
Runoff: medium	**Ground water depth: -**
Vegetation and Land use: mixed deciduous forest	
Described by: Mr. Wutthichart Sirichuaychoo LDD	**Date:** 27 August 2009

Horizon	Depth	Discription
A	0-15	Dusky red (2.5YR3/2) and dark reddish brown (2.5YR3/4) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; neutral (field pH 7.0); clear, smooth, boundary.
BA	15-35	Dark reddish brown (2.5YR3/4) and dusky red (10R3/4) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; common fine and medium, few coarse roots; slightly acid (field pH 6.5); clear, smooth, boundary.
Bt1	35-70	Dusky red (10R3/4) and dark red (10R3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine and coarse roots; moderately acid (field pH 6.0); gradual, smooth, boundary.
Bt2	70-105	Dark red (10R3/6) and red (10R4/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; moderately acid (field pH 6.0); gradual, smooth, boundary.
Bt3	105-140	Dark red (10R3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine and coarse roots; moderately acid (field pH 6.0); gradual, smooth, boundary.
Bt41	140-170	Dark red (10R3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; moderately acid (field pH 6.0); diffuse, smooth, boundary.
Bt42	170-200	Dark red (10R3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; moderately acid (field pH 6.0).

Soil Profile Description

Soil series: ud,hy,f,sh,lb,hc,wd,D,d5		**Profile code No.:** Kea Noi-3	
Soil Classification (1998): very-fine, kaolinitic, hyperthermic Typic Palehumults.			
Location: Kea Noi Royal Project Ban Hoy Luak, Muang Na Sub-District, Chaing Down District, Chiang Mai Province.			
Sheet Name : Ban Na Wai		**Sheet No.:** 4748 II	
Coordinate : 479380E, 2177022N		**Elevation:** 1,040 m. (MSL)	
Relief: rolling		**Slope:** 12-20 %	
Physiography: erosion surface			
Parent material: residuum from shale and limestone			
Drainage: well drained		**Permeability:** moderate	
Runoff: medium		**Ground water depth: -**	
Vegetation and Land use: mixed deciduous forest			
Described by: Mr. Wutthichart Sirichuaychoo LDD		**Date:** 27 August 2009	

Horizon	Depth	Description
A	0-10	Dusky red (2.5YR3/2) clay loam; weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; neutral (field pH 7.0); clear, smooth boundary.
BA	10-30	Dark reddish brown (2.5YR3/4) clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium, few coarse roots; slightly acid (field pH 6.5); clear, smooth boundary.
Bt1	30-55	Dark reddish brown (2.5YR3/4) and dark red (2.5YR3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, slightly plastic; patchy thin clay coating on ped faces; many fine and few coarse roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt2	55-85	Dark red (2.5YR3/6) and dark reddish brown (2.5YR3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; few fine and coarse roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt3	85-120	Dark red (2.5YR3/6) and dark reddish brown (2.5YR3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine and coarse roots; moderately acid (field pH 6.0); gradual, smooth boundary.
Bt41	120-160	Dark red (2.5YR3/6) and dark reddish brown (2.5YR3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; few fine roots; moderately acid (field pH

		6.0); diffuse, smooth boundary.
Bt42	160-200	Dark red (2.5YR3/6) and dark reddish brown (2.5YR3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic; moderately thick clay coating on ped faces; no roots; moderately acid (field pH 6.0).

Soil Profile Description	
Soil series: ud,hy,f,sh,lb,hc,wd,D,d5	**Profile code No.:** Kea Noi-4
Soil Classification (1998): fine, kaolinitic, hyperthermic Typic Palehumults.	
Location: Kea Noi Royal Project Ban loa hu, Muang Na Sub-District, Chaing Down District, Chiang Mai Province.	
Sheet Name: Ban Na Wai	**Sheet No.:** 4748 II
Coordinate: 478481E, 2174442N	**Elevation:** 1,021 m. (MSL)
Relief: rolling	**Slope:** 12-20 **%**
Physiography: erosion surface	
Parent material: residuum from shale and limestone	
Drainage: well drained	**Permeability:** moderate
Runoff: medium	**Ground water depth: -**
Vegetation and Land use: flower	
Other: Near office	
Described by: Mr. Wutthichart Sirichuaychoo LDD	**Date:** 28 August 2009

Horizon	Depth	Discripption
Ap	0-20	Dusky red (10R3/2 and 10R3/3) clay loam; weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; many medium and fine roots; neutral (field pH 7.0); clear, smooth boundary.
Bt1	20-45	Dusky red (10R3/3 and 10R3/4) clay loam; moderate fine and medium subangular blocky structure; firm, slightly sticky, slightly plastic; patchy thin clay coating on ped faces; many fine and medium roots; neutral (field pH 7.0); gradual, smooth boundary.
Bt2	45-70	Dusky red (10R3/4) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; patchy thin clay coating on ped faces; many fine and few medium roots; neutral (field pH 7.0); gradual, smooth boundary.
Bt3	70-100	Dusky red (10R3/4) and dark red (10R3/6) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic, moderately thick clay coating on ped faces; common fine and few medium roots;

		neutral (field pH 7.0); gradual, smooth boundary.
Bt4	100-130	Dark red (10R3/6) and dusky red (10R3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic, moderately thick clay coating on ped faces; few fine and few medium roots; neutral (field pH 7.0); gradual, smooth boundary.
Bt51	130-160	Dark red (10R3/6) and dusky red (10R3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic, moderately thick clay coating on ped faces; few fine roots; neutral (field pH 7.0); diffuse, smooth boundary.
Bt52	160-200	Dark red (10R3/6) and dusky red (10R3/4) clay; moderate medium and coarse breaking to fine and medium subangular blocky structure; firm, sticky, plastic, moderately thick clay coating on ped faces; no roots; neutral (field pH 7.0).

Soil series Symbol: ud,iso,f,sh,lb,wd,D,d5

Profile code number: Nong Keaw -1, native vegetation

Depth (cm)	Horizon	Particle Analysis (% weight)			Sand Fraction Grading					Texture		pH		OM	P (mg/kg)	K (mg/kg)	EC
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl	(%)	(BrayII)	NH_4OAc	(dS/m)
0-10	A	50.6	31.4	18.0	3.0	6.8	11.6	17.3	11.9	L	CL	5.4	4.4	6.38	53	48	-
20-40	BA	34.1	26.3	39.6	2.0	3.9	7.7	11.9	8.6	CL	CL	5.3	4.2	1.04	14	26	-
40-70	Bt1	11.4	25.6	63.0	1.1	1.1	2.3	2.8	4.1	C	C	5.7	4.7	1.27	0	68	-
70-110	Bt2	26.4	22.3	51.3	2.2	2.7	4.6	9.3	7.6	C	C	5.1	4.2	0.76	0	25	-
110-150	Bt3	29.7	21.4	48.9	2.0	3.2	5.4	6.9	12.2	C	C	5.4	4.3	0.35	1	15	-
150-200	Bt4	29.5	22.5	48.0	2.0	3.0	5.3	10.4	8.8	C	C	5.9	4.5	0.60	4	14	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Base saturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-10/20	0.98	33.55	22.84	3.75	1.25	0.06	0.18	5.24	23.64	28.88	17.05	95	31	18	5.71	0.47	7
10/20-40	1.05	31.33	23.80	1.07	0.59	0.03	0.09	1.78	14.37	16.15	8.90	22	20	11	3.10	1.32	8
40-70	1.04	34.73	27.16	2.05	2.12	0.03	0.21	4.41	13.92	18.33	9.62	15	46	24	4.41	0.00	14
70-110	1.04	30.97	23.57	0.19	0.28	0.02	0.07	0.56	13.65	14.21	5.91	12	9	4	1.97	1.41	10
110-150	1.13	30.58	23.63	0.29	0.21	0.03	0.06	0.59	9.62	10.21	5.45	11	11	6	0.92	0.33	12

150-200	1.16	30.39	23.85	0.23	0.10	0.03	0.05	0.41	9.54	9.95	5.19	11	8	4	0.52	0.11	11

Soil series Symbol: ud,iso,f,sh,hb,wd,E,d5

Profile code number: Nong Keaw-2, native vegetation

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-10	A	15.1	42.7	42.2	4.6	2.5	1.8	3.0	3.2	SiC	CL	5.0	4.9	7.64	33	364	-
20/30	BA	7.5	32.0	60.5	1.3	0.7	1.2	1.4	2.9	C	CL	5.3	4.9	3.40	4	336	-
30-55	Bt1	5.9	28.6	65.5	1.4	0.7	0.9	1.4	1.5	C	C	6.0	4.9	1.54	3	235	-
55-90	Bt2	15.6	33.8	50.6	8.5	0.9	1.2	2.1	2.9	C	C	6.1	5.0	1.28	0	170	-
90-130	Bt3	14.0	39.5	46.5	3.1	1.3	1.9	3.2	4.5	C	C	6.1	4.8	0.63	0	225	-
130-160	BC	14.8	46.9	38.3	3.1	1.3	1.8	3.0	5.6	SiCL	C	6.0	4.5	0.94	5	255	-
160-200	Cr	14.8	47.3	37.9	1.4	2.2	2.2	3.4	5.6	SiCL	C	6.0	4.4	0.48	2	319	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Base saturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-10	0.84	40.20	28.38	9.91	6.18	0.06	1.41	17.56	19.45	37.01	27.91	66	63	47	17.56	0.00	19
10-20/30	1.08	40.16	29.70	4.69	3.71	0.04	1.08	9.52	18.64	28.16	20.13	33	47	34	9.89	0.37	18
20/30-55	1.06	39.16	32.81	3.48	3.09	0.04	0.72	7.33	14.52	21.85	13.85	21	53	34	7.33	0.00	14

55-90	1.12	36.16	29.73	3.25	2.60	0.04	0.42	6.31	16.17	22.48	13.86	27	46	28	6.31	0.00	14
90-130	1.19	37.68	29.36	4.93	3.47	0.04	0.61	9.05	13.48	22.53	16.11	35	56	40	9.05	0.00	16
130-160	1.25	36.97	27.65	6.52	5.00	0.05	0.73	12.30	12.69	24.99	19.94	52	62	49	12.77	0.47	15
160-200	-	37.12	26.73	7.52	6.77	0.04	0.80	15.13	14.02	29.15	23.15	61	65	52	15.92	0.79	14

Soil series Symbol: ud,iso,f,sh,lb,wd,C,d5
Profile code number: Nong Keaw-3, corn

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-10/15	A	61.1	17.9	21.0	3.0	6.6	13.1	23.4	15.0	SCL	CL	5.1	4.3	3.40	13	25	-
10/15-30/35	BA	26.1	23.1	50.8	1.4	2.3	4.9	10.5	7.0	C	CL	5.4	4.2	2.84	2	26	-
30/35-75	Bt1	27.9	24.2	47.9	2.1	2.9	4.9	10.5	7.5	C	C	5.5	4.3	2.93	1	16	-
75-115	Bt2	21.7	19.3	59.0	2.8	2.5	3.7	7.4	5.3	C	C	5.8	4.2	1.58	7	12	-
115-160	Bt3	23.4	21.5	55.1	2.4	2.7	3.8	8.5	6.0	C	C	5.5	4.5	0.43	0	15	-
160-200	Bt4	23.6	23.0	53.4	2.1	2.5	3.7	3.4	11.9	C	C	5.7	4.6	0.36	2	18	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Base saturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-10/15	1.00	29.67	23.58	1.17	0.35	0.05	0.11	1.68	15.12	16.80	10.05	48	17	10	3.19	1.51	11
10/15-30/35	0.93	29.14	23.76	0.23	0.14	0.03	0.08	0.48	12.67	13.15	7.30	14	7	4	2.31	1.83	11
30/35-75	1.00	30.08	24.71	0.46	0.14	0.03	0.05	0.68	11.84	12.52	6.32	13	11	5	1.65	0.97	9

75-115	1.12	29.71	24.48	0.25	0.10	0.05	0.05	0.45	11.65	12.10	5.58	9	8	4	0.94	0.49	12
115-160	1.12	30.15	25.07	0.17	0.10	0.16	0.07	0.50	8.27	8.77	5.22	9	10	6	0.77	0.27	11
160-200	1.15	29.62	25.14	0.23	0.07	0.06	0.04	0.40	8.79	9.19	5.01	9	8	4	0.52	0.12	10

Soil series Symbol: ud,iso,f,sh,lb,hc,wd,D,d5

Profile code number: Nong Keaw-4, native vegetation and corn

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-10/15	A	21.5	37.1	41.4	1.9	2.2	3.3	6.9	7.2	C	L	5.3	4.8	4.44	49	315	-
10/15-30/40	BA	17.6	23.5	58.9	1.1	1.3	2.6	0.6	12.0	C	CL	5.3	4.4	1.93	23	96	-
30/40-60/70	Bt1	20.2	21.9	57.9	4.2	1.3	2.3	6.5	5.9	C	C	5.5	4.3	1.87	1	15	-
60/70-100	Bt2	16.9	20.9	62.2	0.9	1.1	2.6	5.7	6.6	C	C	5.9	4.3	0.32	2	44	-
100-130	Bt3	13.9	21.0	65.1	1.0	1.2	2.2	5.1	4.4	C	C	6.0	4.4	0.58	6	37	-
130-160	Bt4	14.5	21.7	63.8	0.9	0.9	2.5	0.7	9.5	C	C	6.0	4.4	0.44	3	34	-
160-200	Bt5	14.8	21.7	63.5	2.2	0.8	2.2	4.7	4.9	C	C	5.7	4.6	0.66	4	22	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Basaturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-10/15	0.89	33.72	24.83	4.38	3.05	0.66	0.86	8.95	17.63	26.58	17.47	42	51	34	8.95	0.00	12
10/15-	1.12	32.26	25.81	2.37	2.08	0.10	0.31	4.86	17.38	22.24	13.68	23	36	22	5.62	0.76	9

30/40																	
30/40-60/70	1.06	36.06	29.85	0.38	0.07	0.28	0.05	0.78	15.49	16.27	9.98	17	8	5	1.83	1.05	7
60/70-100	1.02	33.93	27.36	0.67	0.83	0.05	0.15	1.70	13.92	15.62	8.65	14	20	11	2.83	1.13	14
100-130	1.04	34.27	27.70	0.50	0.59	0.06	0.12	1.27	13.45	14.72	9.09	14	14	9	2.27	1.00	14
130-160	1.10	33.61	27.50	0.48	0.49	0.06	0.10	1.13	13.73	14.86	8.41	13	13	8	1.93	0.80	10
160-200	1.10	33.62	27.62	0.42	0.38	0.03	0.08	0.91	14.00	14.91	7.92	12	11	6	3.44	2.53	12

Soil series Symbol: ud,iso,f,sh,lb,hc,wd,C,d5

Profile code number: Nong Keaw-5, <u>corn, red bean</u>

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-15	Ap	15.0	24.0	61.0	3.7	1.8	1.8	1.3	6.4	C	CL	5.0	4.8	6.69	20	341	-
15-35	Bt1	33.7	34.9	31.4	2.2	2.8	6.0	0.5	22.2	CL	CL	4.9	4.2	5.20	23	33	-
35-70	Bt2	20.0	22.1	57.9	3.2	1.1	2.4	1.4	11.9	C	C	5.3	4.4	2.46	0	31	-
70-100	Bt3	20.6	20.6	58.8	2.7	1.2	2.7	1.5	12.5	C	C	5.7	4.4	1.34	0	18	-
100-130	Bt4	15.4	21.2	63.4	3.2	1.2	2.1	4.8	4.1	C	C	5.7	4.3	0.66	3	14	-
130-170	Bt5	13.8	23.3	62.9	3.7	0.8	1.5	3.8	4.0	C	C	5.9	4.5	1.20	6	17	-
170-200	Bt6	16.7	23.3	60.0	6.3	1.1	1.4	3.6	4.3	C	C	6.0	4.8	0.86	1	15	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Basaturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-15	0.95	35.03	26.65	6.37	1.74	0.05	0.94	9.10	19.02	28.12	16.92	28	54	32	9.10	0.00	10
15-35	0.98	29.47	22.44	1.03	0.28	0.05	0.10	1.46	18.06	19.52	10.39	33	14	7	4.17	2.71	11
35-70	1.02	36.99	28.57	1.49	0.35	0.03	0.10	1.97	15.07	17.04	9.70	17	20	12	2.69	0.72	10

70-100	1.03	37.76	29.89	0.31	0.07	0.04	0.06	0.48	16.76	17.24	8.65	15	6	3	1.59	1.11	10
100-130	1.02	36.34	29.74	1.55	0.03	0.03	0.04	1.65	14.22	15.87	9.80	15	17	10	2.92	1.27	9
130-170	1.04	35.89	29.64	2.83	0.03	0.05	0.06	2.97	13.49	16.46	10.22	16	29	18	4.02	1.05	11
170-200	1.02	35.87	29.79	4.25	0.10	0.04	0.06	4.45	12.88	17.33	9.92	16	45	26	4.45	0.00	10

Soil series Symbol: ud,hy,f,sh,lb,hc,wd,F,d5

Profile code number: Kea Noi-1, <u>corn, red bean</u>

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-20	Aow1	7.9	28.4	63.7	1.4	1.2	1.4	2.1	1.8	C	C	5.6	5.0	3.86	30	517	-
20-45	Aow2	5.7	27.1	67.2	0.3	0.5	0.8	0.2	3.9	C	C	5.5	4.9	2.88	14	145	-
45-55	Ab	9.9	36.4	53.7	1.3	1.2	1.7	0.2	5.5	C	CL	5.3	4.9	3.78	47	95	-
55-80	Bt1	5.6	28.5	65.9	0.7	0.6	0.9	1.6	1.8	C	C	5.4	4.7	4.97	11	68	-
80-105	Bt2	3.6	22.9	73.5	0.4	0.2	0.5	0.7	1.8	C	C	5.6	4.4	3.32	0	60	-
105-130	Bt3	7.5	26.2	66.3	0.5	0.4	0.8	0.8	5.0	C	C	5.7	4.3	7.61	2	71	-
130-160	Bt4	9.7	32.4	57.9	1.5	0.8	1.0	3.6	2.8	C	C	5.8	4.3	6.17	1	95	-
160-200	Bt5	6.3	35.0	58.7	1.5	0.3	0.7	0.6	3.2	C	C	5.7	4.2	3.34	3	82	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Basaturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-20	0.99	39.30	29.66	6.62	2.08	0.04	1.42	10.16	15.83	25.99	15.70	25	65	39	10.16	0.00	16
20-45	0.93	41.07	31.61	5.07	1.91	0.04	0.35	7.37	16.28	23.65	14.04	21	52	31	7.37	0.00	17

45-55	0.98	39.09	29.47	7.42	2.46	0.06	0.30	10.24	18.79	29.03	17.59	33	58	35	10.28	0.04	12
55-80	1.09	39.84	31.09	3.84	2.29	0.05	0.21	6.39	17.03	23.42	13.83	21	46	27	6.45	0.06	17
80-105	1.06	42.30	33.54	0.84	2.43	0.06	0.22	3.55	16.48	20.03	11.74	16	30	18	4.62	1.07	16
105-130	1.10	39.88	32.68	0.67	1.53	0.04	0.24	2.48	17.02	19.50	16.31	25	15	13	3.87	1.39	16
130-160	1.14	39.46	33.21	0.75	1.08	0.06	0.32	2.21	17.45	19.66	11.88	20	19	11	4.14	1.93	17
160-200	1.12	40.08	33.12	0.80	0.83	0.05	0.27	1.95	17.15	19.10	15.11	26	13	10	4.16	2.21	16

Soil series Symbol: ud,hy,f,sh,lb,hc,wd,D,d5

Profile code number: Kea Noi-2, <u>mixed deciduous forest</u>

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-15	A	28.7	36.2	35.1	2.1	2.5	5.6	10.8	7.7	CL	CL	5.7	4.8	7.17	9	285	-
15-35	BA	32.8	33.6	33.6	2.4	1.4	4.4	12.3	12.3	CL	CL	5.4	4.5	3.60	4	56	-
35-70	Bt1	28.7	34.4	36.9	1.0	1.2	4.4	8.0	14.1	CL	C	5.3	4.5	4.75	0	29	-
70-105	Bt2	36.5	26.6	36.9	2.1	1.6	5.0	14.2	13.6	CL	C	5.3	4.6	5.40	3	23	-
105-140	Bt3	34.9	22.8	42.3	1.5	1.3	5.0	13.7	13.4	C	C	5.5	4.6	6.58	9	24	-
140-170	Bt41	35.9	20.9	43.2	2.1	2.3	5.9	1.1	24.5	C	C	5.6	4.5	1.42	4	24	-
170-200	Bt42	33.6	17.1	49.3	0.9	2.5	7.2	14.0	9.0	C	C	5.7	4.3	2.46	3	34	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Basaturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-15	1.08	29.67	22.61	6.27	1.84	0.05	0.75	8.91	15.58	24.49	15.14	43	59	36	8.91	0.00	13
15-35	1.06	27.98	22.10	1.91	0.76	0.05	0.18	2.90	14.55	17.45	8.84	26	33	17	3.08	0.18	13
35-70	1.07	29.43	22.81	0.71	0.42	0.06	0.12	1.31	18.79	20.10	5.81	16	23	6	1.46	0.15	14

70-105	1.00	20.38	23.21	0.42	0.17	0.13	0.09	0.81	11.37	12.18	5.24	14	15	7	1.19	0.38	14
105-140	1.14	29.57	23.84	0.42	0.17	0.05	0.09	0.73	10.42	11.15	6.29	15	12	6	0.82	0.09	12
140-170	1.16	30.61	24.05	0.46	0.10	0.03	0.09	0.68	11.09	11.77	5.23	12	13	6	0.94	0.26	15
170-200	1.20	30.00	24.81	0.31	0.10	0.04	0.11	0.56	11.21	11.77	5.93	12	9	5	1.24	0.68	14

Soil series Symbol: ud,hy,f,sh,lb,hc,wd,D,d5

Profile code number: Kea Noi-3, <u>mixed deciduous forest</u>

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-10	A	24.4	28.5	47.1	6.4	3.1	3.4	5.4	6.1	C	CL	5.4	4.8	5.99	8	504	-
10-30	BA	9.1	26.3	64.6	0.9	1.0	1.7	3.0	2.5	C	CL	5.6	4.2	4.57	8	451	-
30-55	Bt1	14.9	23.2	61.9	0.5	0.6	2.2	6.9	4.7	C	C	5.4	4.2	4.44	3	280	-
55-85	Bt2	14.2	24.0	61.8	0.8	1.0	2.4	5.8	4.2	C	C	5.7	4.2	1.14	3	255	-
85-120	Bt3	26.5	22.7	50.8	1.0	0.7	3.8	12.3	8.7	C	C	5.6	4.2	1.54	5	130	-
120-160	Bt41	19.1	26.2	54.7	2.3	0.7	2.8	3.4	9.9	C	C	5.8	4.1	2.47	2	125	-
160-200	Bt42	22.2	23.1	54.7	1.0	1.2	4.2	6.8	9.0	C	C	5.8	4.1	1.06	6	69	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Basaturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr,) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-10	1.13	31.80	23.34	3.92	3.12	0.04	0.87	7.95	16.28	24.23	15.54	33	51	33	7.95	0.00	16
10-30	1.01	36.56	28.85	2.70	2.74	0.14	0.97	6.55	18.64	25.19	14.97	23	44	26	6.99	0.44	15
30-55	1.02	40.16	31.01	0.67	0.90	0.04	0.40	2.01	20.46	22.47	13.07	21	15	9	4.14	2.13	16

55-85	1.10	38.36	31.13	0.23	0.59	0.29	0.33	1.44	17.41	18.85	12.41	20	12	8	3.82	2.38	16
85-120	0.97	37.85	30.85	0.61	0.66	0.07	0.38	1.72	22.44	24.16	12.50	25	14	7	3.85	2.13	16
120-160	1.03	37.46	30.64	0.21	0.56	0.06	0.34	1.17	16.62	17.79	11.36	21	10	7	3.13	1.96	16
160-200	1.03	40.55	32.87	0.44	0.90	0.08	0.21	1.63	19.96	21.59	12.85	23	13	8	3.82	2.19	16

Soil series Symbol: ud,hy,f,sh,lb,hc,wd,D,d5

Profile code number: Kea Noi-4, Near office

Depth (cm)	Horizon	Particle Analysis (% by weight)			Sand Fraction Grading					Texture		pH		OM (%)	P (mg/kg) (BrayII)	K (mg/kg) NH_4OAc	EC (dS/m)
		sand	silt	clay	vc	c	m	f	vf	lab	field	1:1water	1:1 KCl				
0-20	Ap	36.4	26.8	36.8	1.0	3.0	7.9	14.0	10.5	CL	CL	4.4	4.1	5.96	38	140	-
20-45	Bt1	26.4	25.1	48.5	0.9	1.8	5.3	10.4	8.0	C	CL	5.0	4.3	4.99	7	27	-
45-70	Bt2	28.2	22.7	49.1	1.0	1.6	5.8	11.7	8.1	C	C	5.4	4.5	4.45	9	19	-
70-100	Bt3	36.8	23.2	40.0	0.4	1.4	6.6	15.8	12.6	C	C	5.3	4.5	2.98	5	19	-
100-130	Bt4	35.6	34.0	30.4	0.4	1.6	6.6	14.9	12.1	CL	C	5.6	4.6	1.97	12	23	-
130-160	Bt51	33.2	33.7	33.1	0.5	1.2	5.5	14.3	11.7	CL	C	5.6	4.7	2.29	7	14	-
160-200	Bt52	34.7	23.0	42.3	0.4	1.7	6.2	14.2	12.2	C	C	5.6	4.6	1.51	2	13	-

Depth (cm)	Bulk density g/cm^3	Water Content (%) at 1/3	Water Content (%) at 15	Exchange Capacity and Cation (cmol/kg)									Base saturation (%)		ECEC (cmol/kg) (B+D)	Al (KCl extr) (D)	Fe_2O_3 (%)
				Ca	Mg	Na	K	Sum cations (B)	Extr. Acidity (A)	Sum (B+A)	CEC (NH_4OAc) (C)	CEC (100g clay)	B/Cx100	Bx100/(B+A)			
0-20	0.84	30.63	24.93	0.84	0.45	1.16	0.37	2.82	19.52	22.34	12.15	33	23	13	5.03	2.21	13
20-45	0.94	30.90	25.91	0.92	0.42	0.25	0.09	1.68	17.43	19.11	10.49	22	16	9	2.38	0.70	13
45-70	0.91	31.22	25.96	0.90	0.42	0.06	0.08	1.46	17.61	19.07	7.61	16	19	8	1.76	0.30	13

70-100	0.99	31.07	25.65	0.44	0.38	0.06	0.08	0.96	16.31	17.27	6.74	17	14	6	1.42	0.46	14
100-130	1.09	30.79	25.47	0.17	0.14	0.04	0.05	0.40	12.88	13.28	5.58	18	7	3	0.45	0.05	14
130-160	1.09	34.78	25.53	0.17	0.17	0.06	0.05	0.45	12.71	13.16	5.40	16	8	3	0.45	0.00	13
160-200	1.15	31.40	26.13	0.19	0.14	0.07	0.06	0.46	14.23	14.69	5.54	13	8	3	0.46	0.00	13